2. Trends in Greenhouse Gas Emissions

2.1. Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2008, total U.S. greenhouse gas emissions were 6,946.1 teragrams of carbon dioxide equivalents (Tg CO_2 Eq.); net emissions were 6,005.7 Tg CO_2 Eq. reflecting the influence of sinks (net CO_2 flux from Land Use, Land Use Change, and Forestry).[38] Overall, total U.S. emissions have risen by almost 14 percent from 1990 to 2008. Emissions decreased from 2007 to 2008 by 2.9 percent (206.1 Tg CO_2 Eq.). The following factors were primary contributors to this decrease: (1) a decrease in electricity demand and a resulting decrease in energy consumption, (2) higher energy prices leading to a decrease in energy consumption, and (3) cooler summer conditions in 2008 compared to 2007 reducing energy demand and offsetting the increased energy demand for heating in the colder winter. In addition, the high price of gasoline combined with the economic downturn led to a significant decline in petroleum consumption by the transportation sector in 2008.

Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

Figure 2-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990

As the largest source of U.S. greenhouse gas emissions, carbon dioxide (CO_2) from fossil fuel combustion has accounted for approximately 79 percent of global warming potential (GWP) weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2008. Emissions from this source category grew by 17.7 percent (833.4 Tg CO_2 Eq.) from 1990 to 2008 and were responsible for most of the increase in national emissions during this period. From 2007 to 2008, these emissions decreased by 3.2 percent (184.2 Tg CO_2 Eq.). Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States generally fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than in a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

In the longer-term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses), the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs) and consumer behavior (e.g., walking, bicycling, or telecommuting to work instead of driving).

Energy-related CO_2 emissions also depend on the type of fuel or energy consumed and its carbon (C) intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the CO_2 emissions because of the lower C content of natural gas.

A brief discussion of the year to year variability in fuel combustion emissions is provided below, beginning with 2004.

[38] Estimates are presented in units of teragrams of carbon dioxide equivalent (Tg CO_2 Eq.), which weight each gas by its global warming potential, or GWP, value. (See section on global warming potentials, Executive Summary.)

Emissions from fuel combustion increased from 2004 to 2005 at a rate slightly lower than the average annual growth rate since 1990. A number of factors played a role in this slight increase. This small increase is primarily a result of the restraint on fuel consumption, primarily in the transportation sector, caused by rising fuel prices. Although electricity prices increased slightly, there was a significant increase in electricity consumption in the residential and commercial sectors due to warmer summer weather conditions. This led to an increase in emissions in these sectors with the increased use of air-conditioners. As the amount of fuels used to generate electricity increased among all end-use sectors, electricity emissions increased as well. Despite a slight decrease in industrial energy-related emissions, industrial production and manufacturing output actually increased. The price of natural gas escalated dramatically, causing a decrease in consumption of natural gas in the industrial sector. Use of renewable fuels decreased slightly due to decreased use of biofuels and decreased electricity output by hydroelectric power plants.

From 2005 to 2006, emissions from fuel combustion decreased for the first time since 2000 to 2001. This decrease occurred across all sectors, with the exception of the industrial sector, due to a number of factors. The decrease in emissions from electricity generation is a result of a smaller share of electricity generated by coal and a greater share generated by natural gas. Coal and natural gas consumption for electricity generation decreased by 1.3 percent and increased by 6.0 percent in 2006, respectively, and nuclear power increased by less than 1 percent. The transportation decrease is primarily a result of the restraint on fuel consumption caused by rising fuel prices, which directly resulted in a decrease of petroleum consumption within this sector of about 1.3 percent in 2006. The decrease in emissions from the residential sector is primarily a result of decreased electricity consumption due to increases in the price of electricity, and warmer winter weather conditions. A moderate increase in industrial sector emissions is a result of growth in industrial output and growth in the U.S. economy. Renewable fuels used to generate electricity increased in 2006, with the greatest growth occurring in generation from wind.

After experiencing a decrease from 2005 to 2006, emissions from fuel combustion grew from 2006 to 2007 at a rate somewhat higher than the average growth rate since 1990. There were a number of factors contributing to this increase. Unfavorable weather conditions in both the winter and summer resulted in an increase in consumption of heating fuels, as well as an increase in the demand for electricity. This demand for electricity was met with an increase in coal consumption of 1.7 percent, and with an increase in natural gas consumption of 9.9 percent. This increase in fossil fuel consumption, combined with a 14.7 percent decrease in hydropower generation from 2006 to 2007, resulted in an increase in emissions in 2007. The increase in emissions from the residential and commercial sectors is a result of increased electricity consumption due to warmer summer conditions and cooler winter conditions compared to 2006. In addition to these unfavorable weather conditions, electricity prices remained relatively stable compared to 2006, and natural gas prices decreased slightly. Emissions from the industrial sector increased slightly compared to 2006 as a result of a 1.5 percent increase in industrial production and the increase in fossil fuels used for electricity generation. Despite an overall decrease in electricity generation from renewable energy in 2007 driven by decreases in hydropower generation, wind and solar generation increased significantly.

Emissions from fossil fuel combustion decreased from 2007 to 2008. Several factors contributed to this decrease in emissions. An increase in energy prices coupled with the economic downturn led to a decrease in energy demand and a resulting decrease in emissions from 2007 to 2008. In 2008, the price of coal, natural gas, and petroleum used to generate electricity, as well as the price of fuels used for transportation, increased significantly. As a result of this price increase, coal, natural gas, and petroleum consumption used for electricity generation decreased by 1.3 percent, 2.6 percent, and 27.9 percent, respectively. The increase in the cost of fuels to generate electricity translated into an increase in the price of electricity, leading to a decrease in electricity consumption across all sectors except the commercial sector. The increase in transportation fuel prices led to a decrease in vehicle miles traveled (VMT) and a decrease of 5.7 percent in transportation fossil fuel combustion emissions from 2007 to 2008. Cooler weather conditions in the summer led to a decrease in cooling degree days by 8.7 percent and a decrease in electricity demand compared to 2007, whereas cooler winter conditions led to a 5.6 percent increase in heating degree days compared to 2007 and a resulting increase in demand for heating fuels. The increased emissions from winter heating energy demand was offset by a decrease in emissions from summer cooling related electricity demand. Lastly, renewable energy[39] generation increased by 7.1 percent from 2007 to 2008, driven by a significant increase in solar and wind energy used to generate electricity (of 12 percent and 51 percent, respectively). This increase in renewable energy generation contributed to a decrease in the carbon intensity of electricity generation.

[39] Renewable energy includes the following energy sources: hydroelectric power, geothermal energy, biofuels, solar energy, and wind energy.

Overall, from 1990 to 2008, total emissions of CO_2 increased by 815.4 Tg CO_2 Eq. (16.0 percent), while CH_4 and N_2O emissions decreased by 46.1 Tg CO_2 Eq. (7.5 percent) and 3.6 Tg CO_2 Eq. (about 1.1 percent) respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 63.7 Tg CO_2 Eq. (70.4 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high GWPs and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by C sequestration in managed forests, trees in urban areas, agricultural soils, and landfilled yard trimmings, which was estimated to be 13.5 percent of total emissions in 2008.

Table 2-1 summarizes emissions and sinks from all U.S. anthropogenic sources in weighted units of Tg CO_2 Eq., while unweighted gas emissions and sinks in gigagrams (Gg) are provided in Table 2-2.

Table 2-1: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CO_2	**5,090.0**	**5,417.3**	**5,965.3**	**6,089.0**	**6,001.9**	**6,103.0**	**5,905.5**
Fossil Fuel Combustion	4,718.9	5,016.9	5,575.7	5,728.6	5,631.8	5,736.5	5,552.3
Electricity Generation	1,804.6	1,935.8	2,279.5	2,377.3	2,325.7	2,391.3	2,342.0
Transportation	1,485.8	1,608.0	1,809.5	1,895.4	1,876.7	1,893.8	1,785.3
Industrial	844.5	861.9	851.8	825.2	850.1	842.8	819.8
Residential	339.4	353.4	371.3	358.7	322.2	342.0	343.0
Commercial	216.7	223.2	227.7	221.4	206.1	217.5	219.7
U.S. Territories	27.9	34.5	35.9	50.6	50.9	49.1	42.5
Non-Energy Use of Fuels	118.4	138.2	145.0	136.4	141.6	135.5	132.9
Iron and Steel Production & Metallurgical Coke Production	109.8	103.1	95.1	73.2	76.1	77.4	74.5
Cement Production	33.3	36.8	41.2	45.9	46.6	45.2	41.1
Natural Gas Systems	37.3	42.2	29.4	29.5	29.5	30.8	30.0
Lime Production	11.5	13.3	14.1	14.4	15.1	14.6	14.3
Incineration of Waste	8.0	11.5	11.3	12.6	12.7	13.3	13.1
Ammonia Production and Urea Consumption	16.8	17.8	16.4	12.8	12.3	14.0	11.8
Cropland Remaining Cropland	7.1	7.0	7.5	7.9	7.9	8.3	7.6
Limestone and Dolomite Use	5.1	6.7	5.1	6.8	8.0	6.2	7.1
Aluminum Production	6.8	5.7	6.1	4.1	3.8	4.3	4.5
Soda Ash Production and Consumption	4.1	4.3	4.2	4.2	4.2	4.1	4.1
Petrochemical Production	3.3	4.1	4.5	4.2	3.8	3.9	3.4
Titanium Dioxide Production	1.2	1.5	1.8	1.8	1.8	1.9	1.8
Carbon Dioxide Consumption	1.4	1.4	1.4	1.3	1.7	1.9	1.8
Ferroalloy Production	2.2	2.0	1.9	1.4	1.5	1.6	1.6
Phosphoric Acid Production	1.5	1.5	1.4	1.4	1.2	1.2	1.2
Wetlands Remaining Wetlands	1.0	1.0	1.2	1.1	0.9	1.0	0.9
Petroleum Systems	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Zinc Production	0.9	1.0	1.1	0.5	0.5	0.4	0.4
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.3	0.2	0.2	0.2	0.2	0.2
Land Use, Land-Use Change, and Forestry (Sink)[a]	*(909.4)*	*(842.9)*	*(664.2)*	*(950.4)*	*(959.2)*	*(955.4)*	*(940.3)*
Biomass—Wood	*215.2*	*229.1*	*218.1*	*206.9*	*207.9*	*207.4*	*198.4*
International Bunker Fuels[b]	*111.8*	*99.8*	*98.5*	*110.5*	*129.1*	*127.1*	*135.2*
Biomass—Ethanol[b]	*4.2*	*7.7*	*9.2*	*22.6*	*30.5*	*38.3*	*53.3*
CH_4	**613.4**	**613.2**	**586.1**	**553.2**	**568.2**	**569.2**	**567.3**
Enteric Fermentation	132.4	143.7	136.8	136.7	139.0	141.2	140.8
Landfills	149.3	144.1	120.7	125.6	127.1	126.5	126.3
Natural Gas Systems	129.5	132.6	130.7	103.6	103.1	99.5	96.4
Coal Mining	84.1	67.1	60.5	56.9	58.3	58.1	67.3

Manure Management	29.3	33.9	38.6	42.2	42.3	45.9	45.0
Petroleum Systems	33.9	32.0	30.2	28.2	28.2	28.8	29.1
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4	24.3
Forest Land Remaining Forest Land	3.2	4.3	14.3	9.8	21.6	20.0	11.9
Rice Cultivation	7.1	7.6	7.5	6.8	5.9	6.2	7.2
Stationary Combustion	7.4	7.1	6.6	6.6	6.2	6.5	6.7
Abandoned Underground Coal Mines	6.0	8.2	7.4	5.6	5.5	5.7	5.9
Mobile Combustion	4.7	4.3	3.4	2.5	2.3	2.2	2.0
Composting	0.3	0.7	1.3	1.6	1.6	1.7	1.7
Field Burning of Agricultural Residues	0.8	0.7	0.9	0.9	0.9	1.0	1.0
Petrochemical Production	0.9	1.1	1.2	1.1	1.0	1.0	0.9
Iron and Steel Production & Metallurgical Coke Production	1.0	1.0	0.9	0.7	0.7	0.7	0.6
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.2*	*0.2*	*0.2*
N_2O	**322.7**	**343.2**	**346.5**	**329.4**	**330.4**	**328.7**	**319.1**
Agricultural Soil Management	203.5	205.9	210.1	215.8	211.2	211.0	215.9
Mobile Combustion	43.9	54.0	53.2	36.9	33.6	30.3	26.1
Nitric Acid Production	19.8	22.0	21.7	18.4	18.1	21.5	19.9
Manure Management	14.4	15.5	16.7	16.6	17.3	17.3	17.1
Stationary Combustion	12.8	13.3	14.5	14.7	14.5	14.6	14.2
Forest Land Remaining Forest Land	2.7	3.7	12.1	8.4	18.0	16.7	10.1
Wastewater Treatment	3.7	4.0	4.5	4.7	4.8	4.9	4.9
N_2O from Product Uses	4.4	4.6	4.9	4.4	4.4	4.4	4.4
Adipic Acid Production	15.3	17.3	5.5	5.2	4.3	3.7	2.0
Composting	0.4	0.8	1.4	1.7	1.8	1.8	1.8
Settlements Remaining Settlements	1.0	1.2	1.1	1.5	1.5	1.6	1.6
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Incineration of Waste	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
International Bunker Fuels[b]	*1.1*	*0.9*	*0.9*	*1.0*	*1.2*	*1.2*	*1.2*
HFCs	**36.9**	**62.2**	**103.2**	**119.3**	**121.8**	**127.4**	**130.2**
Substitution of Ozone Depleting Substances[c]	0.3	29.0	74.3	103.2	107.7	110.1	113.0
HCFC-22 Production	36.4	33.0	28.6	15.8	13.8	17.0	17.0
Semiconductor Manufacture	0.2	0.3	0.3	0.2	0.3	0.3	0.3
PFCs	**20.8**	**15.6**	**13.5**	**6.2**	**6.0**	**7.5**	**7.5**
Aluminum Production	18.5	11.8	8.6	3.0	2.5	3.8	3.8
Semiconductor Manufacture	2.2	3.8	4.9	3.2	3.5	3.6	3.6
SF_6	**32.8**	**28.1**	**19.2**	**17.9**	**17.0**	**16.5**	**16.5**
Electrical Transmission and Distribution	26.8	21.6	15.1	14.0	13.2	12.7	12.7
Magnesium Production and Processing	5.4	5.6	3.0	2.9	2.9	3.0	3.0
Semiconductor Manufacture	0.5	0.9	1.1	1.0	1.0	0.8	0.8
Total	**6,116.6**	**6,479.7**	**7,033.7**	**7,114.9**	**7,045.4**	**7,152.1**	**6,946.1**
Net Emissions (Sources and Sinks)	**5,207.2**	**5,636.9**	**6,369.5**	**6,164.5**	**6,086.3**	**6,196.7**	**6,005.7**

+ Does not exceed 0.05 Tg CO_2 Eq.

[a] The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Parentheses indicate negative values or sequestration.

[b] Emissions from International Bunker Fuels and Wood Biomass and Ethanol Consumption are not included in totals.

[c] Small amounts of PFC emissions also result from this source.
Note: Totals may not sum due to independent rounding.

Table 2-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Gg)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CO_2	**5,090,049**	**5,417,330**	**5,965,343**	**6,089,031**	**6,001,920**	**6,102,951**	**5,905,470**
Fossil Fuel Combustion	4,718,945	5,016,877	5,575,723	5,728,608	5,631,767	5,736,487	5,552,330
Electricity Generation	1,804,606	1,935,778	2,279,473	2,377,342	2,325,669	2,391,277	2,341,963
Transportation	1,485,819	1,607,994	1,809,548	1,895,357	1,876,704	1,893,785	1,785,288
Industrial	844,521	861,905	851,821	825,220	850,138	842,791	819,839
Residential	339,410	353,448	371,301	358,666	322,235	342,002	342,998
Commercial	216,708	223,239	227,728	221,396	206,078	217,540	219,712
U.S. Territories	27,882	34,513	35,853	50,627	50,942	49,092	42,530
Non-Energy Use of Fuels	118,370	138,233	144,987	136,421	141,597	135,501	132,892
Iron and Steel Production & Metallurgical Coke Production	109,760	103,116	95,062	73,190	76,100	77,370	74,517
Cement Production	33,278	36,847	41,190	45,910	46,562	45,229	41,147
Natural Gas Systems	37,317	42,249	29,394	29,472	29,526	30,816	29,973
Lime Production	11,533	13,325	14,088	14,379	15,100	14,595	14,344
Incineration of Waste	8,049	11,461	11,270	12,616	12,684	13,289	13,128
Ammonia Production and Urea Consumption	16,831	17,796	16,402	12,849	12,300	13,968	11,755
Cropland Remaining Cropland	7,084	7,049	7,541	7,854	7,875	8,319	7,638
Limestone and Dolomite Use	5,127	6,651	5,056	6,768	8,035	6,182	7,088
Aluminum Production	6,831	5,659	6,086	4,142	3,801	4,251	4,477
Soda Ash Production and Consumption	4,141	4,304	4,181	4,228	4,162	4,140	4,111
Petrochemical Production	3,311	4,101	4,479	4,181	3,837	3,931	3,449
Titanium Dioxide Production	1,195	1,526	1,752	1,755	1,836	1,930	1,809
Carbon Dioxide Consumption	1,416	1,422	1,421	1,321	1,709	1,867	1,780
Ferroalloy Production	2,152	2,036	1,893	1,392	1,505	1,552	1,599
Phosphoric Acid Production	1,529	1,513	1,382	1,386	1,167	1,166	1,187
Wetlands Remaining Wetlands	1,033	1,018	1,227	1,079	879	1,012	941
Petroleum Systems	555	528	534	490	488	474	453
Zinc Production	929	993	1,115	506	513	411	402
Lead Production	285	298	311	266	270	267	276
Silicon Carbide Production and Consumption	375	329	248	219	207	196	175
Land Use, Land-Use Change, and Forestry (Sink)[a]	*(909,422)*	*(842,852)*	*(664,247)*	*(950,396)*	*(959,158)*	*(955,410)*	*(940,349)*
Wood Biomass and Ethanol Consumption[b]	*219,341*	*236,775*	*227,276*	*229,419*	*238,323*	*245,706*	*251,763*
International Bunker Fuels[b]	*111,828*	*99,817*	*98,482*	*110,505*	*129,104*	*127,054*	*135,226*
CH_4	**29,209**	**29,202**	**27,907**	**26,341**	**27,058**	**27,105**	**27,015**
Enteric Fermentation	6,303	6,844	6,513	6,509	6,619	6,723	6,707
Landfills	7,111	6,860	5,747	5,980	6,050	6,023	6,016
Natural Gas Systems	6,169	6,313	6,223	4,935	4,907	4,738	4,591
Coal Mining	4,003	3,193	2,881	2,710	2,776	2,765	3,206
Manure Management	1,395	1,612	1,837	2,011	2,015	2,183	2,144
Petroleum Systems	1,613	1,524	1,439	1,344	1,344	1,372	1,384
Wastewater Treatment	1,120	1,183	1,199	1,158	1,166	1,162	1,158
Forest Land Remaining Forest Land	152	203	681	467	1,027	953	568
Rice Cultivation	339	363	357	326	282	295	343
Stationary Combustion	353	340	315	312	294	309	319

Abandoned Underground Coal Mines	288	392	350	266	264	269	281
Mobile Combustion	223	204	160	119	112	105	97
Composting	15	35	60	75	75	79	80
Field Burning of Agricultural Residues	36	35	42	44	43	46	46
Petrochemical Production	41	52	59	51	48	48	43
Iron and Steel Production & Metallurgical Coke Production	46	47	44	34	35	33	31
Ferroalloy Production	1	1	1	+	+	+	+
Silicon Carbide Production and Consumption	1	1	1	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	*8*	*6*	*6*	*7*	*8*	*7*	*8*
N_2O	**1,041**	**1,107**	**1,118**	**1,062**	**1,066**	**1,060**	**1,029**
Agricultural Soil Management	656	664	678	696	681	681	696
Mobile Combustion	142	174	172	119	108	98	84
Nitric Acid Production	64	71	70	59	58	69	64
Manure Management	47	50	54	54	56	56	55
Stationary Combustion	41	43	47	47	47	47	46
Forest Land Remaining Forest Land	9	12	39	27	58	54	33
Wastewater Treatment	12	13	14	15	15	16	16
N_2O from Product Uses	14	15	16	14	14	14	14
Adipic Acid Production	49	56	18	17	14	12	7
Composting	1	3	4	6	6	6	6
Settlements Remaining Settlements	3	4	4	5	5	5	5
Field Burning of Agricultural Residues	1	1	2	2	2	2	2
Incineration of Waste	2	1	1	1	1	1	1
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
International Bunker Fuels[b]	*3*	*3*	*3*	*3*	*4*	*4*	*4*
HFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances[c]	M	M	M	M	M	M	M
HCFC-22 Production	3	3	2	1	1	1	1
Semiconductor Manufacture	+	+	+	+	+	+	+
PFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Aluminum Production	M	M	M	M	M	M	M
Semiconductor Manufacture	M	M	M	M	M	M	M
SF_6	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Electrical Transmission and Distribution	1	1	1	1	1	1	1
Magnesium Production and Processing	+	+	+	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+

+ Does not exceed 0.5 Gg.
M Mixture of multiple gases
[a] The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Parentheses indicate negative values or sequestration.
[b] Emissions from International Bunker Fuels and Wood Biomass and Ethanol Consumption are not included in totals.
[c] Small amounts of PFC emissions also result from this source.
Note: Totals may not sum due to independent rounding.

Emissions of all gases can be summed from each source category from Intergovernmental Panel on Climate Change (IPCC) guidance. Over the nineteen-year period of 1990 to 2008, total emissions in the Energy, Industrial Processes, and Agriculture sectors grew by 770.9 Tg CO_2 Eq. (15 percent), 19.7 Tg CO_2 Eq. (6 percent), and 39.7 Tg CO_2 Eq. (10 percent), respectively. Emissions decreased in the Waste and Solvent and Other Product Use sectors by 18.1 Tg CO_2 Eq. (10 percent) and less than 0.1 Tg CO_2 Eq. (less than 0.4 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry sector increased by 30.9 Tg CO_2 Eq. (3.4 percent).

Figure 2-4: U.S. Greenhouse Gas Emissions by Chapter/IPCC Sector

Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO_2 Eq.)

Chapter/IPCC Sector	1990	1995	2000	2005	2006	2007	2008
Energy	5,206.1	5,528.4	6,068.8	6,163.0	6,068.2	6,162.6	5,977.0
Industrial Processes	326.1	347.3	359.9	341.3	346.1	355.3	345.8
Solvent and Other Product Use	4.4	4.6	4.9	4.4	4.4	4.4	4.4
Agriculture	387.8	407.7	410.9	419.7	417.2	423.0	427.5
Land Use, Land-Use Change, and Forestry (Emissions)	15.0	17.2	36.3	28.6	49.8	47.6	32.2
Waste	177.2	174.5	153.0	158.0	159.7	159.3	159.1
Total Emissions	**6,116.6**	**6,479.7**	**7,033.7**	**7,114.9**	**7,045.4**	**7,152.1**	**6,946.1**
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Sinks)*	(909.4)	(842.9)	(664.2)	(950.4)	(959.2)	(955.4)	(940.3)
Net Emissions (Sources and Sinks)	**5,207.2**	**5,636.9**	**6,369.5**	**6,164.5**	**6,086.3**	**6,196.7**	**6,005.7**

* The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Please refer to Table 2-9 for a breakout by source.
Note: Totals may not sum due to independent rounding.
Note: Parentheses indicate negative values or sequestration.

Energy

Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2008. In 2008, approximately 84 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 16 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure 2-5 and Figure 2-6). A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy consumption is presented in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (37 percent and 13 percent of total U.S. emissions of each gas, respectively). Table 2-4 presents greenhouse gas emissions from the Energy chapter, by source and gas.

Figure 2-5: 2008 Energy Chapter Greenhouse Gas Sources

Figure 2-6: 2008 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)

Table 2-4: Emissions from Energy (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CO_2	**4,883.2**	**5,209.3**	**5,761.9**	**5,907.6**	**5,816.1**	**5,916.6**	**5,728.8**
Fossil Fuel Combustion	4,718.9	5,016.9	5,575.7	5,728.6	5,631.8	5,736.5	5,552.3
Electricity Generation	1,804.6	1,935.8	2,279.5	2,377.3	2,325.7	2,391.3	2,342.0

Transportation	1,485.8	1,608.0	1,809.5	1,895.4	1,876.7	1,893.8	1,785.3
Industrial	844.5	861.9	851.8	825.2	850.1	842.8	819.8
Residential	339.4	353.4	371.3	358.7	322.2	342.0	343.0
Commercial	216.7	223.2	227.7	221.4	206.1	217.5	219.7
U.S. Territories	27.9	34.5	35.9	50.6	50.9	49.1	42.5
Non-Energy Use of Fuels	118.4	138.2	145.0	136.4	141.6	135.5	132.9
Natural Gas Systems	37.3	42.2	29.4	29.5	29.5	30.8	30.0
Incineration of Waste	8.0	11.5	11.3	12.6	12.7	13.3	13.1
Petroleum Systems	0.6	0.5	0.5	0.5	0.5	0.5	0.5
*Wood Biomass and Ethanol Consumption**	*219.3*	*236.8*	*227.3*	*229.4*	*238.3*	*245.7*	*251.8*
*International Bunker Fuels**	*111.8*	*99.8*	*98.5*	*110.5*	*129.1*	*127.1*	*135.2*
CH_4	**265.6**	**251.3**	**238.7**	**203.4**	**203.6**	**200.7**	**207.4**
Natural Gas Systems	129.5	132.6	130.7	103.6	103.1	99.5	96.4
Coal Mining	84.1	67.1	60.5	56.9	58.3	58.1	67.3
Petroleum Systems	33.9	32.0	30.2	28.2	28.2	28.8	29.1
Stationary Combustion	7.4	7.1	6.6	6.6	6.2	6.5	6.7
Abandoned Underground Coal Mines	6.0	8.2	7.4	5.6	5.5	5.7	5.9
Mobile Combustion	4.7	4.3	3.4	2.5	2.3	2.2	2.0
Incineration of Waste	+	+	+	+	+	+	+
*International Bunker Fuels**	*0.2*	*0.1*	*0.1*	*0.1*	*0.2*	*0.2*	*0.2*
N_2O	**57.2**	**67.8**	**68.1**	**52.0**	**48.5**	**45.3**	**40.8**
Mobile Combustion	43.9	54.0	53.2	36.9	33.6	30.3	26.1
Stationary Combustion	12.8	13.3	14.5	14.7	14.5	14.6	14.2
Incineration of Waste	0.5	0.5	0.4	0.4	0.4	0.4	0.4
*International Bunker Fuels**	*1.1*	*0.9*	*0.9*	*1.0*	*1.2*	*1.2*	*1.2*
Total	**5,206.1**	**5,528.4**	**6,068.8**	**6,163.0**	**6,068.2**	**6,162.6**	**5,977.0**

+ Does not exceed 0.05 Tg CO_2 Eq.

* These values are presented for informational purposes only and are not included in totals or are already accounted for in other source categories.

Note: Totals may not sum due to independent rounding.

CO_2 emissions from fossil fuel combustion are presented in Table 2-5 based on the underlying U.S. energy consumer data collected by EIA. Estimates of CO_2 emissions from fossil fuel combustion are calculated from these EIA "end-use sectors" based on total consumption and appropriate fuel properties (any additional analysis and refinement of the EIA data is further explained in the Energy chapter of this report). EIA's fuel consumption data for the electric power sector comprises electricity-only and combined-heat-and-power (CHP) plants within the NAICS 22 category whose primary business is to sell electricity, or electricity and heat, to the public (nonutility power producers can be included in this sector as long as they meet they electric power sector definition). EIA statistics for the industrial sector include fossil fuel consumption that occurs in the fields of manufacturing, agriculture, mining, and construction. EIA's fuel consumption data for the transportation sector consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. EIA's fuel consumption data for the industrial sector consists of all facilities and equipment used for producing, processing, or assembling goods (EIA includes generators that produce electricity and/or useful thermal output primarily to support on-site industrial activities in this sector). EIA's fuel consumption data for the residential sector consists of living quarters for private households. EIA's fuel consumption data for the commercial sector consists of service-providing facilities and equipment from private and public organizations and businesses (EIA includes generators that produce electricity and/or useful thermal output primarily to support the activities at commercial establishments in this sector). Table 2-5, Figure 2-7, and Figure 2-8 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

Table 2-5: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (Tg CO_2 Eq.)

End-Use Sector	1990	1995	2000	2005	2006	2007	2008
Transportation	**1,488.8**	**1,611.0**	**1,813.0**	**1,900.0**	**1,881.2**	**1,898.8**	**1,789.9**
Combustion	1,485.8	1,608.0	1,809.5	1,895.4	1,876.7	1,893.8	1,785.3

Electricity	3.0	3.0	3.4	4.7	4.5	5.0	4.6
Industrial	**1,525.2**	**1,573.7**	**1,635.6**	**1,554.6**	**1,555.9**	**1,566.2**	**1,505.1**
Combustion	844.5	861.9	851.8	825.2	850.1	842.8	819.8
Electricity	680.6	711.8	783.8	729.3	705.7	723.4	685.3
Residential	**927.2**	**991.3**	**1,127.9**	**1,206.6**	**1,145.7**	**1,190.5**	**1,177.1**
Combustion	339.4	353.4	371.3	358.7	322.2	342.0	343.0
Electricity	587.7	637.8	756.6	847.9	823.5	848.5	834.1
Commercial	**749.9**	**806.4**	**963.4**	**1,016.8**	**998.0**	**1,031.9**	**1,037.6**
Combustion	216.7	223.2	227.7	221.4	206.1	217.5	219.7
Electricity	533.2	583.1	735.6	795.4	792.0	814.4	817.9
U.S. Territories[a]	**27.9**	**34.5**	**35.9**	**50.6**	**50.9**	**49.1**	**42.5**
Total	**4,718.9**	**5,016.9**	**5,575.7**	**5,728.6**	**5,631.8**	**5,736.5**	**5,552.3**
Electricity Generation	**1,804.6**	**1,935.8**	**2,279.5**	**2,377.3**	**2,325.7**	**2,391.3**	**2,342.0**

Note: Totals may not sum due to independent rounding. Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector.

Figure 2-7: 2008 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure 2-8: 2008 End-Use Sector Emissions from Fossil Fuel Combustion

The main driver of emissions in the energy sector is CO_2 from fossil fuel combustion. The transportation end-use sector accounted for 1,789.9 Tg CO_2 Eq. in 2008, or approximately 32 percent of total CO_2 emissions from fossil fuel combustion, the largest share of any end-use sector.[40] The industrial end-use sector accounted for 27 percent of CO_2 emissions from fossil fuel combustion. The residential and commercial end-use sectors accounted for an average 21 and 19 percent, respectively, of CO_2 emissions from fossil fuel combustion. Both end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances contributing to about 71 and 79 percent of emissions from the residential and commercial end-use sectors, respectively. Significant trends in emissions from energy source categories over the nineteen-year period from 1990 through 2008 included the following:

- Total CO_2 emissions from fossil fuel combustion increased from 4,718.9 Tg CO_2 Eq. to 5,552.3 Tg CO_2 Eq.—an 18 percent total increase over the nineteen-year period. From 2007 to 2008, these emissions decreased by 184.2 Tg CO_2 Eq. (3.2 percent).
- CO_2 emissions from non-energy use of fossil fuels have increased 14.5 Tg CO_2 Eq. (12.3 percent) from 1990 through 2008. Emissions from non-energy uses of fossil fuels were 132.9 Tg CO_2 Eq. in 2008, which constituted 2.3 percent of total national CO_2 emissions.
- CH_4 emissions from natural gas systems were 96.4 Tg CO_2 Eq. in 2008; emissions have declined by 33.1 Tg CO_2 Eq. (25.6 percent) since 1990. This decline has been due to improvements in technology and management practices, as well as replacement of old equipment.
- CH_4 emissions from coal mining were 67.3 Tg CO_2 Eq. In 2008, a decline in emissions of 16.7 Tg CO_2 Eq. (19.9 percent) from 1990, is a result of the mining of less gassy coal from underground mines and the increased use of CH_4 collected from degasification systems.
- In 2008, N_2O emissions from mobile combustion were 26.1 Tg CO_2 Eq. (approximately 8.2 percent of U.S. N_2O emissions). From 1990 to 2008, N_2O emissions from mobile combustion decreased by 40.5 percent. However, from 1990 to 1998 emissions increased by 26 percent, due to control technologies that reduced NO_x emissions while increasing N_2O emissions. Since 1998, newer control technologies have led to a steady decline in N_2O from this source.

[40] Note that electricity generation is the largest emitter of CO_2 when electricity is not distributed among end-use sectors.

- CO_2 emissions from incineration of waste (13.1 Tg CO_2 Eq. in 2008) increased by 5.1 Tg CO_2 Eq. (63 percent) from 1990 through 2008, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

Industrial Processes

Greenhouse gas emissions are produced as the by-products of many non-energy-related industrial activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production and urea consumption, lime production, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production (see Figure 2-9). Industrial processes also release HFCs, PFCs and SF_6. In addition to their use as ODS substitutes, HFCs, PFCs, SF_6, and other fluorinated compounds are employed and emitted by a number of other industrial sources in the United States. These industries include aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

Figure 2-9: 2008 Industrial Processes Chapter Greenhouse Gas Sources

Table 2-6: Emissions from Industrial Processes (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CO_2	**198.7**	**199.9**	**194.7**	**172.5**	**177.1**	**177.1**	**168.1**
Iron and Steel Production and Metallurgical Coke Production	109.8	103.1	95.1	73.2	76.1	77.4	74.5
Iron and Steel Production	*104.3*	*98.1*	*90.7*	*69.3*	*72.4*	*73.6*	*69.2*
Metallurgical Coke Production	*5.5*	*5.0*	*4.4*	*3.8*	*3.7*	*3.8*	*5.3*
Cement Production	33.3	36.8	41.2	45.9	46.6	45.2	41.1
Lime Production	11.5	13.3	14.1	14.4	15.1	14.6	14.3
Ammonia Production & Urea Consumption	16.8	17.8	16.4	12.8	12.3	14.0	11.8
Limestone and Dolomite Use	5.1	6.7	5.1	6.8	8.0	6.2	7.1
Aluminum Production	6.8	5.7	6.1	4.1	3.8	4.3	4.5
Soda Ash Production and Consumption	4.1	4.3	4.2	4.2	4.2	4.1	4.1
Petrochemical Production	3.3	4.1	4.5	4.2	3.8	3.9	3.4
Titanium Dioxide Production	1.2	1.5	1.8	1.8	1.8	1.9	1.8
Carbon Dioxide Consumption	1.4	1.4	1.4	1.3	1.7	1.9	1.8
Ferroalloy Production	2.2	2.0	1.9	1.4	1.5	1.6	1.6
Phosphoric Acid Production	1.5	1.5	1.4	1.4	1.2	1.2	1.2
Zinc Production	0.9	1.0	1.1	0.5	0.5	0.4	0.4
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.3	0.2	0.2	0.2	0.2	0.2
CH_4	**1.9**	**2.1**	**2.2**	**1.8**	**1.7**	**1.7**	**1.6**
Petrochemical Production	0.9	1.1	1.2	1.1	1.0	1.0	0.9
Iron and Steel Production and Metallurgical Coke Production	1.0	1.0	0.9	0.7	0.7	0.7	0.6
Iron and Steel Production	*1.0*	*1.0*	*0.9*	*0.7*	*0.7*	*0.7*	*0.6*
Metallurgical Coke Production	+	+	+	+	+	+	+
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+

N_2O	**35.1**	**39.4**	**27.2**	**23.6**	**22.4**	**25.2**	**21.9**
Nitric Acid Production	19.8	22.0	21.7	18.4	18.1	21.5	19.9
Adipic Acid Production	15.3	17.3	5.5	5.2	4.3	3.7	2.0
HFCs	**36.9**	**62.2**	**103.2**	**119.3**	**121.8**	**127.4**	**130.2**
Substitution of Ozone Depleting Substances[a]	0.3	29.0	74.3	103.2	107.7	110.1	113.0
HCFC-22 Manufacture	36.4	33.0	28.6	15.8	13.8	17.0	17.0
Semiconductor Manufacturing HFCs	0.2	0.3	0.3	0.2	0.3	0.3	0.3
PFCs	**20.8**	**15.6**	**13.5**	**6.2**	**6.0**	**7.5**	**7.5**
Aluminum Production	18.5	11.8	8.6	3.0	2.5	3.8	3.8
Semiconductor Manufacturing PFCs	2.2	3.8	4.9	3.2	3.5	3.6	3.6
SF_6	**32.8**	**28.1**	**19.2**	**17.9**	**17.0**	**16.5**	**16.5**
Electrical Transmission and Distribution	26.8	21.6	15.1	14.0	13.2	12.7	12.7
Magnesium Production and Processing	5.4	5.6	3.0	2.9	2.9	3.0	3.0
Semiconductor Manufacturing SF_6	0.5	0.9	1.1	1.0	1.0	0.8	0.8
Total	**326.1**	**347.3**	**359.9**	**341.3**	**346.1**	**355.3**	**345.8**

+ Does not exceed 0.05 Tg CO_2 Eq.

[a] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

Overall, emissions from industrial processes increased by 6.0 percent from 1990 to 2008 despite decreases in emissions from several industrial processes, such as iron and steel production and metallurgical coke production, aluminum production, HCFC-22 production, and electrical transmission and distribution. The increase in overall emissions was driven by a rise in the emissions originating from cement manufacture and, primarily, the emissions from the use of substitutes for ozone depleting substances. Significant trends in emissions from industrial processes source categories over the nineteen-year period from 1990 through 2008 included the following:

- HFC emissions from ODS substitutes have been increasing from small amounts in 1990 to 113.0 Tg CO_2 Eq. in 2008. This increase results from efforts to phase out CFCs and other ODSs in the United States. In the short term, this trend is expected to continue, and will likely accelerate over the next decade as HCFCs—which are interim substitutes in many applications—are phased out under the provisions of the Copenhagen Amendments to the Montreal Protocol.
- CO_2 and CH_4 emissions from iron and steel production and metallurgical coke production decreased by 3.7 percent to 75.2 Tg CO_2 Eq. in 2008, and have declined overall by 35.6 Tg CO_2 Eq. (32.1 percent) from 1990 through 2008, due to restructuring of the industry, technological improvements, and increased scrap utilization.
- PFC emissions from aluminum production decreased by about 79 percent (14.7 Tg CO_2 Eq.) from 1990 to 2008, due to both industry emission reduction efforts and lower domestic aluminum production.
- N_2O emissions from adipic acid production were 2.0 Tg CO_2 Eq. in 2008, and have decreased significantly in recent years from the widespread installation of pollution control measures. These emissions from adipic acid production have decreased nearly 87 percent since 1990, and except for slight increases in 2002 and 2003 these declined by 62 percent from 1998 to 2008.
- CO_2 emissions from ammonia production and urea application (11.8 Tg CO_2 Eq. in 2008) have decreased by 5.1 Tg CO_2 Eq. (30 percent) since 1990, due to a decrease in domestic ammonia production. This decrease in ammonia production can be attributed to market fluctuations and high natural gas prices.

Solvent and Other Product Use

Greenhouse gas emissions are produced as a by-product of various solvent and other product uses. In the United States, N_2O Emissions from Product Uses, the only source of greenhouse gas emissions from this sector, accounted for 4.4 Tg CO_2 Eq., or less than 0.1 percent of total U.S. emissions in 2008 (see Table 2-7).

Table 2-7: N_2O Emissions from Solvent and Other Product Use (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008

N_2O	**4.4**	**4.6**	**4.9**	**4.4**	**4.4**	**4.4**	**4.4**
N_2O from Product Uses	4.4	4.6	4.9	4.4	4.4	4.4	4.4
Total	**4.4**	**4.6**	**4.9**	**4.4**	**4.4**	**4.4**	**4.4**

In 2008, N_2O emissions from product uses constituted slightly more than 1 percent of U.S. N_2O emissions. From 1990 to 2008, emissions from this source category decreased by less than 0.5 percent, though slight increases occurred in intermediate years.

Agriculture

Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues.

In 2008, agricultural activities were responsible for emissions of 427.5 Tg CO_2 Eq., or 6.2 percent of total U.S. greenhouse gas emissions. CH_4 and N_2O were the primary greenhouse gases emitted by agricultural activities. CH_4 emissions from enteric fermentation and manure management represented about 25 percent and 8 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2008. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. N_2O emissions in 2008, accounting for almost 68 percent.

Figure 2-10: 2008 Agriculture Chapter Greenhouse Gas Sources

Table 2-8: Emissions from Agriculture (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CH_4	**169.6**	**185.9**	**183.7**	**186.7**	**188.1**	**194.2**	**194.0**
Enteric Fermentation	132.4	143.7	136.8	136.7	139.0	141.2	140.8
Manure Management	29.3	33.9	38.6	42.2	42.3	45.9	45.0
Rice Cultivation	7.1	7.6	7.5	6.8	5.9	6.2	7.2
Field Burning of Agricultural Residues	0.8	0.7	0.9	0.9	0.9	1.0	1.0
N_2O	**218.3**	**221.8**	**227.2**	**233.0**	**229.1**	**228.8**	**233.5**
Agricultural Soil Management	203.5	205.9	210.1	215.8	211.2	211.0	215.9
Manure Management	14.4	15.5	16.7	16.6	17.3	17.3	17.1
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Total	**387.8**	**407.7**	**410.9**	**419.7**	**417.2**	**423.0**	**427.5**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Agriculture include the following:

- Agricultural soils produced approximately 68 percent of N_2O emissions in the United States in 2008. Estimated emissions from this source in 2008 were 215.9 Tg CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2008, although overall emissions were 6.1 percent higher in 2008 than in 1990. N2O emissions from this source have not shown any significant long-term trend, as their estimation is highly sensitive to the amount of N applied to soils, which has not changed significantly over the time-period, and to weather patterns and crop type.

- Enteric fermentation was the largest source of CH_4 emissions in 2008, at 140.8 Tg CO_2 Eq. Although emissions from enteric fermentation have increased by 6.4 percent between 1990 and 2008, emissions increased about 9 percent between 1990 and 1995 and decreased about 6 percent from 1995 to 2004, mainly due to decreasing populations of both beef and dairy cattle and improved feed quality for feedlot cattle. Emissions increased by 5 percent from 2004 through 2007, as both dairy and beef populations

increased and the literature for dairy cow diets indicated a trend toward a decrease in feed digestibility. Emissions decreased again in 2008 as beef cattle populations decreased again. During this timeframe, populations of sheep have decreased 48 percent since 1990 while horse populations have increased by almost 87 percent, mostly over the last seven years. Goat and swine populations have increased 1 percent and 25 percent, respectively, during this timeframe.

- Overall, emissions from manure management increased 42 percent between 1990 and 2008. This encompassed an increase of 54 percent for CH_4, from 29.3 Tg CO_2 Eq. in 1990 to 45.0 Tg CO_2 Eq. in 2008; and an increase of almost 19 percent for N_2O, from 14.4 Tg CO_2 Eq. in 1990 to 17.1 Tg CO_2 Eq. in 2008. The majority of this increase was from swine and dairy cow manure, since the general trend in manure management is one of increasing use of liquid systems, which tends to produce greater CH_4 emissions.

Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also alter the background carbon fluxes between biomass, soils, and the atmosphere. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps have resulted in an uptake (sequestration) of carbon in the United States, which offset about 14 percent of total U.S. greenhouse gas emissions in 2008. Forests (including vegetation, soils, and harvested wood) accounted for approximately 84 percent of total 2008 net CO_2 flux, urban trees accounted for 10 percent, mineral and organic soil carbon stock changes accounted for 5 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total net flux in 2008. The net forest sequestration is a result of net forest growth, increasing forest area, and a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth and increased urban forest size. In agricultural soils, mineral and organic soils sequester approximately 70 percent more C than is emitted from these soils through liming, urea fertilization, or both. The mineral soil C sequestration is largely due to the conversion of cropland to hay production fields, the limited use of bare-summer fallow areas in semi-arid areas, and an increase in the adoption of conservation tillage practices. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard trimming carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2008 resulted in a net C sequestration of 940.3 Tg CO_2 Eq. (256.5 Tg C). (Table 2-9). This represents an offset of approximately 16 percent of total U.S. CO_2 emissions, or 14 percent of total greenhouse gas emissions in 2008. Between 1990 and 2008, total land use, land-use change, and forestry net C flux resulted in a 3.4 percent increase in CO_2 sequestration.

Table 2-9: Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Sink Category	1990	1995	2000	2005	2006	2007	2008
Forest Land Remaining Forest Land	(729.8)	(692.6)	(467.7)	(806.6)	(812.5)	(806.9)	(791.9)
Cropland Remaining Cropland	(29.4)	(22.9)	(30.2)	(18.3)	(19.1)	(19.7)	(18.1)
Land Converted to Cropland	2.2	2.9	2.4	5.9	5.9	5.9	5.9
Grassland Remaining Grassland	(52.0)	(26.7)	(52.6)	(9.0)	(8.9)	(8.8)	(8.7)
Land Converted to Grassland	(19.8)	(22.3)	(27.3)	(24.6)	(24.5)	(24.3)	(24.2)
Settlements Remaining Settlements	(57.1)	(67.3)	(77.5)	(87.8)	(89.8)	(91.9)	(93.9)
Other (Landfilled Yard Trimmings and Food Scraps)	(23.5)	(13.9)	(11.3)	(10.1)	(10.3)	(9.8)	(9.5)
Total	**(909.4)**	**(842.9)**	**(664.2)**	**(950.4)**	**(959.2)**	**(955.4)**	**(940.3)**

Note: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

Land use, land-use change, and forestry source categories also resulted in emissions of CO_2, CH_4, and N_2O that are not included in the net CO_2 flux estimates presented in Table 2-10. The application of crushed limestone and dolomite to managed land (i.e., soil liming) and urea fertilization resulted in CO_2 emissions of 7.6 Tg CO_2 Eq. in 2008, an increase of about 8 percent relative to 1990. Lands undergoing peat extraction resulted in CO_2 emissions of 0.9 Tg CO_2 Eq. (941 Gg), and N_2O emissions of less than 0.01 Tg CO_2 Eq. N_2O emissions from the application of synthetic fertilizers to forest soils have increased from 1990 to 0.4 Tg CO_2 Eq. in 2008. Settlement soils in 2008 resulted in direct N_2O emissions of 1.6 Tg CO_2 Eq., a 61 percent increase relative to 1990. Non-CO_2 emissions from

forest fires in 2008 resulted in CH_4 emissions of 11.9 Tg CO_2 Eq., and in N_2O emissions of 9.7 Tg CO_2 Eq. (Table 2-10).

Table 2-10: Emissions from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Source Category	1990	1995	2000	2005	2006	2007	2008
CO_2	**8.1**	**8.1**	**8.8**	**8.9**	**8.8**	**9.3**	**8.6**
Cropland Remaining Cropland: Liming of Agricultural Soils	4.7	4.4	4.3	4.3	4.2	4.5	3.8
Cropland Remaining Cropland: Urea Fertilization	2.4	2.7	3.2	3.5	3.7	3.8	3.8
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	1.0	1.0	1.2	1.1	0.9	1.0	0.9
CH_4	**3.2**	**4.3**	**14.3**	**9.8**	**21.6**	**20.0**	**11.9**
Forest Land Remaining Forest Land: Forest Fires	3.2	4.3	14.3	9.8	21.6	20.0	11.9
N_2O	**3.7**	**4.9**	**13.2**	**9.8**	**19.5**	**18.3**	**11.7**
Forest Land Remaining Forest Land: Forest Fires	2.6	3.5	11.7	8.0	17.6	16.3	9.7
Forest Land Remaining Forest Land: Forest Soils	0.1	0.2	0.4	0.4	0.4	0.4	0.4
Settlements Remaining Settlements: Settlement Soils	1.0	1.2	1.1	1.5	1.5	1.6	1.6
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
Total	**15.0**	**17.2**	**36.3**	**28.6**	**49.8**	**47.6**	**32.2**

+ Less than 0.05 Tg CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Other significant trends from 1990 to 2008 in land use, land-use change, and forestry emissions include:

- Net C sequestration by forest land has increased 9 percent. This is primarily due to increased forest management and the effects of previous reforestation. The increase in intensive forest management resulted in higher growth rates and higher biomass density. The tree planting and conservation efforts of the 1970s and 1980s continue to have a significant impact on sequestration rates. Finally, the forested area in the United States increased over the past 19 years, although only at an average rate of 0.23 percent per year.
- Net sequestration of C by urban trees has increased by 65 percent over the period from 1990 to 2008. This is primarily due to an increase in urbanized land area in the United States.
- Annual C sequestration in landfilled yard trimmings and food scraps has decreased by 59 percent since 1990. This is due in part to a decrease in the amount of yard trimmings and food scraps generated. In addition, the proportion of yard trimmings and food scraps landfilled has decreased, as there has been a significant rise in the number of municipal composting facilities in the United States.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-11). In 2008, landfills were the second largest source of anthropogenic CH_4 emissions, accounting for 22 percent of total U.S. CH_4 emissions.[41] Additionally, wastewater treatment accounts for 4 percent of U.S. CH_4 emissions, and 2 percent of N_2O emissions. Emissions of CH_4 and N_2O from composting grew from 1990 to 2008, and resulted in emissions of 3.5 Tg CO_2 Eq. in 2008. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-11.

[41] Landfills also store carbon, due to incomplete degradation of organic materials such as wood products and yard trimmings, as described in the Land Use, Land-Use Change, and Forestry chapter.

Figure 2-11: 2008 Waste Chapter Greenhouse Gas Sources

Overall, in 2008, waste activities generated emissions of 159.1 Tg CO_2 Eq., or 2.3 percent of total U.S. greenhouse gas emissions.

Table 2-11: Emissions from Waste (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CH_4	**173.2**	**169.6**	**147.1**	**151.5**	**153.1**	**152.5**	**152.3**
Landfills	149.3	144.1	120.7	125.6	127.1	126.5	126.3
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4	24.3
Composting	0.3	0.7	1.3	1.6	1.6	1.7	1.7
N_2O	**4.0**	**4.8**	**5.8**	**6.5**	**6.6**	**6.7**	**6.8**
Wastewater Treatment	3.7	4.0	4.5	4.7	4.8	4.9	4.9
Composting	0.4	0.8	1.4	1.7	1.8	1.8	1.8
Total	**177.2**	**174.5**	**153.0**	**158.0**	**159.7**	**159.3**	**159.1**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Waste include the following:

- From 1990 to 2008, net CH_4 emissions from landfills decreased by 23.0 Tg CO_2 Eq. (15 percent), with small increases occurring in interim years. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted,[42] which has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled.
- From 1990 to 2008, CH_4 and N_2O emissions from wastewater treatment increased by 0.8 Tg CO_2 Eq. (3.5 percent) and 1.3 Tg CO_2 Eq. (34 percent), respectively.
- CH_4 and N_2O emissions from composting each increased by less than 0.1 Tg CO_2 Eq. (1 percent) from 2007 to 2008. Emissions from composting have been continually increasing since 1990, from 0.7 Tg CO_2 Eq. to 3.5 Tg CO_2 Eq. in 2008, an over four-fold increase over the time series.

2.2. Emissions by Economic Sector

Throughout this report, emission estimates are grouped into six sectors (i.e., chapters) defined by the IPCC and detailed above: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change, and Forestry; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following U.S. economic sectors: residential, commercial, industry, transportation, electricity generation, and agriculture, as well as U.S. territories.

Using this categorization, emissions from electricity generation accounted for the largest portion (34 percent) of U.S. greenhouse gas emissions in 2008. Transportation activities, in aggregate, accounted for the second largest portion (27 percent). Emissions from industry accounted for about 19 percent of U.S. greenhouse gas emissions in 2008. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 20 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for 5 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 7 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2

[42] The CO_2 produced from combusted landfill CH_4 at landfills is not counted in national inventories as it is considered part of the natural C cycle of decomposition.

from fossil fuel combustion. The commercial sector accounted for roughly 6 percent of emissions, while U.S. territories accounted for about 1 percent.

CO_2 was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Table 2-12 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-12 shows the trend in emissions by sector from 1990 to 2008.

Figure 2-12: Emissions Allocated to Economic Sectors

Table 2-12: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2008)

Sector/Source	1990	1995	2000	2005	2006	2007	2008	Percent[a]
Electric Power Industry	**1,851.2**	**1,981.7**	**2,319.4**	**2,418.8**	**2,366.7**	**2,431.7**	**2,382.5**	**34.3%**
CO_2 from Fossil Fuel Combustion	1,804.6	1,935.8	2,279.5	2,377.3	2,325.7	2,391.3	2,342.0	33.7%
Incineration of Waste	8.5	11.9	11.7	13.0	13.1	13.7	13.5	0.2%
Electrical Transmission and Distribution	26.8	21.6	15.1	14.0	13.2	12.7	12.7	0.2%
Stationary Combustion	8.6	9.1	10.6	11.0	10.8	11.0	10.8	0.2%
Limestone and Dolomite Use	2.6	3.3	2.5	3.4	4.0	3.1	3.5	0.1%
Transportation	**1,545.1**	**1,695.2**	**1,932.3**	**2,016.1**	**1,993.0**	**2,003.5**	**1,886.1**	**27.2%**
CO_2 from Fossil Fuel Combustion	1,485.8	1,608.0	1,809.5	1,895.4	1,876.7	1,893.8	1,785.3	25.7%
Substitution of Ozone Depleting Substances	+	19.0	55.7	72.9	72.2	68.8	64.9	0.9%
Mobile Combustion	47.4	56.9	55.1	37.6	34.1	30.7	26.4	0.4%
Non-Energy Use of Fuels	11.8	11.3	12.1	10.2	9.9	10.2	9.5	0.1%
Industry	**1,512.1**	**1,534.0**	**1,475.5**	**1,356.9**	**1,386.2**	**1,380.1**	**1,352.8**	**19.5%**
CO_2 from Fossil Fuel Combustion	813.5	825.3	813.0	778.4	801.1	794.4	774.4	11.1%
Natural Gas Systems	166.9	174.8	160.1	133.1	132.6	130.3	126.4	1.8%
Non-Energy Use of Fuels	100.8	120.9	122.0	118.2	122.8	116.8	116.2	1.7%
Iron and Steel Production & Metallurgical Coke Production	110.7	104.1	96.0	73.9	76.8	78.1	75.2	1.1%
Coal Mining	84.1	67.1	60.5	56.9	58.3	58.1	67.3	1.0%
Cement Production	33.3	36.8	41.2	45.9	46.6	45.2	41.1	0.6%
Petroleum Systems	34.4	32.5	30.7	28.7	28.7	29.3	29.5	0.4%
Nitric Acid Production	19.8	22.0	21.7	18.4	18.1	21.5	19.9	0.3%
HCFC-22 Production	36.4	33.0	28.6	15.8	13.8	17.0	17.0	0.2%
Lime Production	11.5	13.3	14.1	14.4	15.1	14.6	14.3	0.2%
Ammonia Production and Urea Consumption	16.8	17.8	16.4	12.8	12.3	14.0	11.8	0.2%
Aluminum Production	25.4	17.5	14.7	7.1	6.3	8.1	8.3	0.1%
Substitution of Ozone Depleting Substances	+	1.2	3.1	5.2	5.7	6.1	6.6	0.1%
Abandoned Underground Coal Mines	6.0	8.2	7.4	5.6	5.5	5.7	5.9	0.1%
Semiconductor Manufacture	2.9	4.9	6.2	4.4	4.7	4.7	4.7	0.1%
N_2O from Product Uses	4.4	4.6	4.9	4.4	4.4	4.4	4.4	0.1%
Petrochemical Production	4.2	5.2	5.7	5.3	4.8	4.9	4.4	0.1%

Soda Ash Production and Consumption	4.1	4.3	4.2	4.2	4.2	4.1	4.1	0.1%
Stationary Combustion	4.7	4.9	4.8	4.4	4.6	4.5	4.1	0.1%
Limestone and Dolomite Use	2.6	3.3	2.5	3.4	4.0	3.1	3.5	0.1%
Magnesium Production and Processing	5.4	5.6	3.0	2.9	2.9	3.0	3.0	+
Adipic Acid Production	15.3	17.3	5.5	5.2	4.3	3.7	2.0	+
Titanium Dioxide Production	1.2	1.5	1.8	1.8	1.8	1.9	1.8	+
Carbon Dioxide Consumption	1.4	1.4	1.4	1.3	1.7	1.9	1.8	+
Ferroalloy Production	2.2	2.0	1.9	1.4	1.5	1.6	1.6	+
Mobile Combustion	0.9	1.0	1.1	1.3	1.3	1.3	1.3	+
Phosphoric Acid Production	1.5	1.5	1.4	1.4	1.2	1.2	1.2	+
Zinc Production	0.9	1.0	1.1	0.5	0.5	0.4	0.4	+
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	+
Silicon Carbide Production and Consumption	0.4	0.3	0.3	0.2	0.2	0.2	0.2	+
Agriculture	**433.2**	**460.8**	**485.3**	**494.1**	**515.1**	**518.0**	**504.1**	**7.3%**
N_2O from Agricultural Soil Management	203.5	205.9	210.1	215.8	211.2	211.0	215.9	3.1%
Enteric Fermentation	132.4	143.7	136.8	136.7	139.0	141.2	140.8	2.0%
Manure Management	43.7	49.3	55.2	58.9	59.6	63.2	62.1	0.9%
CO_2 from Fossil Fuel Combustion	31.04	36.60	38.79	46.81	49.04	48.44	45.44	0.7%
CH_4 and N_2O from Forest Fires	5.8	7.7	26.0	17.8	39.2	36.3	21.7	0.3%
Rice Cultivation	7.1	7.6	7.5	6.8	5.9	6.2	7.2	0.1%
Liming of Agricultural Soils	4.7	4.4	4.3	4.3	4.2	4.5	3.8	0.1%
Urea Fertilization	2.4	2.7	3.2	3.5	3.7	3.8	3.8	0.1%
Field Burning of Agricultural Residues	1.2	1.1	1.4	1.5	1.4	1.5	1.5	+
CO_2 and N_2O from Managed Peatlands	1.0	1.0	1.2	1.1	0.9	1.0	0.9	+
Mobile Combustion	0.3	0.4	0.4	0.5	0.5	0.5	0.5	+
N_2O from Forest Soils	0.1	0.2	0.4	0.4	0.4	0.4	0.4	+
Stationary Combustion	+	+	+	+	+	+	+	+
Commercial	**395.2**	**399.6**	**387.4**	**399.1**	**389.3**	**404.6**	**411.2**	**5.9%**
CO_2 from Fossil Fuel Combustion	216.7	223.2	227.7	221.4	206.1	217.5	219.7	3.2%
Landfills	149.3	144.1	120.7	125.6	127.1	126.5	126.3	1.8%
Substitution of Ozone Depleting Substances	+	0.7	5.5	18.5	22.4	26.6	31.1	0.4%
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4	24.3	0.4%
Human Sewage	3.7	4.0	4.5	4.7	4.8	4.9	4.9	0.1%
Composting	0.7	1.5	2.6	3.3	3.3	3.5	3.5	0.1%
Stationary Combustion	1.2	1.3	1.2	1.2	1.1	1.2	1.2	+
Residential	**346.2**	**367.7**	**386.8**	**371.0**	**335.1**	**356.4**	**359.5**	**5.2%**
CO_2 from Fossil Fuel Combustion	339.4	353.4	371.3	358.7	322.2	342.0	343.0	4.9%
Substitution of Ozone Depleting Substances	0.3	8.1	10.1	6.5	7.5	8.6	10.3	0.1%
Stationary Combustion	5.5	5.0	4.3	4.3	3.9	4.2	4.6	0.1%
Settlement Soil Fertilization	1.0	1.2	1.1	1.5	1.5	1.6	1.6	+
U.S. Territories	**33.7**	**40.7**	**46.9**	**58.9**	**60.0**	**57.8**	**49.9**	**0.7%**

CO_2 from Fossil Fuel Combustion	27.9	34.5	35.9	50.6	50.9	49.1	42.5	0.6%
Non-Energy Use of Fuels	5.7	6.0	10.9	8.1	8.9	8.5	7.2	0.1%
Stationary Combustion	0.1	0.1	0.1	0.2	0.2	0.2	0.2	+
Total Emissions	**6,116.6**	**6,479.7**	**7,033.7**	**7,114.9**	**7,045.4**	**7,152.1**	**6,946.1**	**100.0%**
Sinks	**(909.4)**	**(842.9)**	**(664.2)**	**(950.4)**	**(959.2)**	**(955.4)**	**(940.3)**	**-13.5%**
CO_2 Flux from Forests	(729.8)	(692.6)	(467.7)	(806.6)	(812.5)	(806.9)	(791.9)	-11.4%
Urban Trees	(57.1)	(67.3)	(77.5)	(87.8)	(89.8)	(91.9)	(93.9)	-1.4%
CO_2 Flux from Agricultural Soil Carbon Stocks	(99.1)	(69.0)	(107.7)	(45.9)	(46.5)	(46.9)	(45.0)	-0.6%
Landfilled Yard Trimmings and Food Scraps	(23.5)	(13.9)	(11.3)	(10.1)	(10.3)	(9.8)	(9.5)	-0.1%
Net Emissions	**5,207.2**	**5,636.9**	**6,369.5**	**6,164.5**	**6,086.3**	**6,196.7**	**6,005.7**	**86.5%**

Note: Includes all emissions of CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Parentheses indicate negative values or sequestration.
Totals may not sum due to independent rounding.
ODS (Ozone Depleting Substances)
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.
[a] Percent of total emissions for year 2008.

Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 34 percent of total U.S. greenhouse gas emissions in 2008. Emissions increased by 29 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. Electricity generation-related emissions decreased from 2007 to 2008 by 2 percent, primarily due to decreased CO_2 emissions from fossil fuel combustion. The electricity generation sector in the United States is composed of traditional electric utilities as well as other entities, such as power marketers and non-utility power producers. The majority of electricity generated by these entities was through the combustion of coal in boilers to produce high-pressure steam that is passed through a turbine. Table 2-13 provides a detailed summary of emissions from electricity generation-related activities.

Table 2-13: Electricity Generation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Fuel Type or Source	1990	1995	2000	2005	2006	2007	2008
CO_2	**1,815.2**	**1,950.6**	**2,293.3**	**2,393.3**	**2,342.4**	**2,407.7**	**2,358.6**
CO_2 from Fossil Fuel Combustion	1,804.6	1,935.8	2,279.5	2,377.3	2,325.7	2,391.3	2,342.0
Coal	*1,531.1*	*1,648.5*	*1,909.9*	*1,958.7*	*1,932.7*	*1,965.4*	*1,940.7*
Natural Gas	*175.5*	*228.2*	*280.9*	*319.1*	*338.2*	*371.7*	*362.0*
Petroleum	*97.5*	*58.7*	*88.4*	*99.2*	*54.4*	*53.9*	*38.9*
Geothermal	*0.4*	*0.3*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	8.0	11.5	11.3	12.6	12.7	13.3	13.1
Limestone and Dolomite Use	2.6	3.3	2.5	3.4	4.0	3.1	3.5
CH_4	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Stationary Combustion*	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Incineration of Waste	+	+	+	+	+	+	+
N_2O	**8.5**	**9.0**	**10.4**	**10.7**	**10.5**	**10.6**	**10.5**
Stationary Combustion*	8.1	8.6	10.0	10.3	10.1	10.2	10.1
Incineration of Waste	0.5	0.5	0.4	0.4	0.4	0.4	0.4
SF_6	**26.8**	**21.6**	**15.1**	**14.0**	**13.2**	**12.7**	**12.7**
Electrical Transmission and Distribution	26.8	21.6	15.1	14.0	13.2	12.7	12.7
Total	**1,851.2**	**1,981.7**	**2,319.4**	**2,418.8**	**2,366.7**	**2,431.7**	**2,382.5**

Note: Totals may not sum due to independent rounding.
* Includes only stationary combustion emissions related to the generation of electricity.
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity (EIA 2009a and Duffield 2006). These three source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, and SF_6 from Electrical Transmission and Distribution Systems.[43]

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (29 percent), followed closely by emissions from transportation activities, which account for 27 percent of total emissions. Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption. In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-14 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-13 shows the trend in these emissions by sector from 1990 to 2008.

Figure 2-13: Emissions with Electricity Distributed to Economic Sectors

Table 2-14: U.S Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (Tg CO_2 Eq.) and Percent of Total in 2008

Sector/Gas	1990	1995	2000	2005	2006	2007	2008	Percent[a]
Industry	**2,179.6**	**2,226.6**	**2,239.9**	**2,069.8**	**2,077.2**	**2,083.6**	**2,018.0**	**29.1%**
Direct Emissions	1,512.1	1,534.0	1,475.5	1,356.9	1,386.2	1,380.1	1,352.8	19.5%
CO_2	1,110.5	1,142.9	1,127.2	1,065.7	1,097.0	1,085.1	1,055.2	15.2%
CH_4	294.8	286.5	262.5	227.7	228.5	226.7	232.2	3.3%
N_2O	43.4	48.1	36.2	32.1	31.1	33.7	30.2	0.4%
HFCs, PFCs, and SF_6	63.3	56.6	49.6	31.3	29.6	34.7	35.1	0.5%
Electricity-Related	667.5	692.5	764.4	713.0	691.0	703.5	665.2	9.6%
CO_2	654.5	681.6	755.8	705.4	683.9	696.5	658.5	9.5%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0%
N_2O	3.1	3.2	3.4	3.2	3.1	3.1	2.9	0.0%
SF_6	9.7	7.5	5.0	4.1	3.9	3.7	3.5	0.1%
Transportation	**1,548.2**	**1,698.3**	**1,935.8**	**2,020.9**	**1,997.5**	**2,008.6**	**1,890.8**	**27.2%**
Direct Emissions	1,545.1	1,695.2	1,932.3	2,016.1	1,993.0	2,003.5	1,886.1	27.2%
CO_2	1,497.6	1,619.3	1,821.6	1,905.5	1,886.6	1,904.0	1,794.8	25.8%
CH_4	4.5	4.0	3.1	2.2	2.0	1.9	1.7	0.0%
N_2O	42.9	52.9	51.9	35.5	32.1	28.8	24.7	0.4%
HFCs[b]	+	19.0	55.7	72.9	72.2	68.8	64.9	0.9%
Electricity-Related	3.1	3.1	3.5	4.8	4.6	5.1	4.7	0.1%
CO_2	3.0	3.1	3.4	4.7	4.5	5.0	4.7	0.1%
CH_4	+	+	+	+	+	+	+	0.0%
N_2O	+	+	+	+	+	+	+	0.0%
SF_6	+	+	+	+	+	+	+	0.0%
Commercial	**942.1**	**996.6**	**1,135.9**	**1,208.4**	**1,195.2**	**1,232.7**	**1,243.2**	**17.9%**
Direct Emissions	395.2	399.6	387.4	399.1	389.3	404.6	411.2	5.9%

[43] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

CO_2	216.7	223.2	227.7	221.4	206.1	217.5	219.7	3.2%
CH_4	174.0	170.5	148.0	152.4	154.0	153.4	153.2	2.2%
N_2O	4.4	5.2	6.2	6.8	6.9	7.0	7.1	0.1%
HFCs	+	0.7	5.5	18.5	22.4	26.6	31.1	0.4%
Electricity-Related	547.0	597.0	748.5	809.3	805.9	828.2	832.1	12.0%
CO_2	536.3	587.6	740.1	800.8	797.6	820.0	823.7	11.9%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0%
N_2O	2.5	2.7	3.3	3.6	3.6	3.6	3.7	0.1%
SF_6	7.9	6.5	4.9	4.7	4.5	4.3	4.4	0.1%
Residential	**949.1**	**1,020.7**	**1,156.7**	**1,233.7**	**1,173.1**	**1,219.2**	**1,208.1**	**17.4%**
Direct Emissions	346.2	367.7	386.8	371.0	335.1	356.4	359.5	5.2%
CO_2	339.4	353.4	371.3	358.7	322.2	342.0	343.0	4.9%
CH_4	4.4	4.0	3.4	3.4	3.1	3.4	3.7	0.1%
N_2O	2.1	2.2	2.1	2.4	2.3	2.5	2.5	0.0%
HFCs	0.3	8.1	10.1	6.5	7.5	8.6	10.3	0.1%
Electricity-Related	602.9	653.0	769.9	862.7	838.0	862.8	848.6	12.2%
CO_2	591.2	642.7	761.2	853.6	829.4	854.3	840.1	12.1%
CH_4	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.0%
N_2O	2.8	3.0	3.4	3.8	3.7	3.8	3.7	0.1%
SF_6	8.7	7.1	5.0	5.0	4.7	4.5	4.5	0.1%
Agriculture	**463.9**	**496.9**	**518.4**	**523.3**	**542.3**	**550.2**	**536.1**	**7.7%**
Direct Emissions	433.2	460.8	485.3	494.1	515.1	518.0	504.1	7.3%
CO_2	39.2	44.7	47.6	55.7	57.8	57.8	54.0	0.8%
CH_4	172.9	190.3	198.2	196.7	209.9	214.3	206.1	3.0%
N_2O	221.2	225.8	239.6	241.7	247.4	245.9	244.0	3.5%
Electricity-Related	30.7	36.1	33.1	29.1	27.2	32.2	32.0	0.5%
CO_2	30.1	35.6	32.7	28.8	26.9	31.9	31.6	0.5%
CH_4	+	+	+	+	+	+	+	0.0%
N_2O	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0%
SF_6	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.0%
U.S. Territories	**33.7**	**40.7**	**46.9**	**58.9**	**60.0**	**57.8**	**49.9**	**0.7%**
Total	**6,116.6**	**6,479.7**	**7,033.7**	**7,114.9**	**7,045.4**	**7,152.1**	**6,946.1**	**100.0%**

Note: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector.
Totals may not sum due to independent rounding.
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.
[a] Percent of total emissions for year 2008.
[b] Includes primarily HFC-134a.

Industry

The industrial end-use sector includes CO_2 emissions from fossil fuel combustion from all manufacturing facilities, in aggregate. This sector also includes emissions that are produced as a by-product of the non-energy-related industrial process activities. The variety of activities producing these non-energy-related emissions, to name a few includes fugitive CH_4 emissions from coal mining, by-product CO_2 emissions from cement manufacture, and HFC, PFC, and SF_6 by-product emissions from semiconductor manufacture. Overall, direct industry sector emissions have declined since 1990, while electricity-related emissions have risen. In theory, emissions from the industrial end-use sector should be highly correlated with economic growth and industrial output, but heating of industrial buildings and agricultural energy consumption are also affected by weather conditions. In addition, structural changes within the U.S. economy that lead to shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment) also have a significant affect on industrial emissions.

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 27 percent of U.S. greenhouse gas emissions in 2008. The largest sources of transportation GHGs in 2008 were

passenger cars (33 percent), light duty trucks, which include sport utility vehicles, pickup trucks, and minivans (29 percent), freight trucks (21 percent) and commercial aircraft (7 percent). These figures include direct emissions from fossil fuel combustion, as well as HFC emissions from mobile air conditioners and refrigerated transport allocated to these vehicle types. Table 2-15 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals.

From 1990 to 2008, transportation emissions rose by 22 percent due, in large part, to increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet. The number of vehicle miles traveled by light-duty motor vehicles (passenger cars and light-duty trucks) increased 37 percent from 1990 to 2008, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices over much of this period. A similar set of social and economic trends has led to a significant increase in air travel and freight transportation by both air and road modes during the time series.

Although average fuel economy over this period increased slightly due primarily to the retirement of older vehicles, average fuel economy among new vehicles sold annually gradually declined from 1990 to 2004. The decline in new vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light duty trucks, which grew from about one-fifth of new vehicle sales in the 1970s to slightly over half of the market by 2004. Increasing fuel prices have since decreased the momentum of light duty truck sales, and average new vehicle fuel economy has improved since 2005 as the market share of passenger cars increased. VMT growth among all passenger vehicles has also been impacted, remaining stagnant from 2004 to 2008, compared to an annual rate of 2.5 percent over the period 1990 to 2004.

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half being related to gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder. The primary driver of transportation-related emissions was CO_2 from fossil fuel combustion, which increased by 20 percent from 1990 to 2008. This rise in CO_2 emissions, combined with an increase in HFCs from virtually no emissions in 1990 to 64.9 Tg CO_2 Eq. in 2008, led to an increase in overall emissions from transportation activities of 22 percent.

Table 2-15: Transportation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Vehicle Type	1990	1995	2000	2005	2006	2007	2008
Passenger Cars	**657.3**	**645.9**	**695.2**	**709.3**	**682.6**	**671.6**	**632.1**
CO_2	629.2	606.7	644.1	662.0	638.8	632.4	597.5
CH_4	2.6	2.1	1.6	1.1	1.0	0.9	0.8
N_2O	25.4	26.9	25.2	17.8	15.7	13.8	11.7
HFCs	+	10.1	24.3	28.4	27.1	24.6	22.1
Light-Duty Trucks	**336.5**	**436.5**	**512.0**	**551.0**	**563.6**	**569.9**	**552.4**
CO_2	321.0	406.4	466.9	505.6	519.2	528.0	513.7
CH_4	1.4	1.4	1.1	0.7	0.7	0.6	0.6
N_2O	14.1	22.1	22.4	13.7	12.6	11.2	9.5
HFCs	+	6.5	21.7	31.0	31.2	30.1	28.6
Medium- and Heavy-Duty Trucks	**231.1**	**277.7**	**354.5**	**408.3**	**418.6**	**425.2**	**401.2**
CO_2	230.1	274.8	345.8	396.0	406.0	412.5	388.6
CH_4	0.2	0.2	0.1	0.1	0.1	0.1	0.1
N_2O	0.8	1.0	1.2	1.1	1.1	1.1	1.0
HFCs	+	1.7	7.4	11.1	11.4	11.5	11.6
Buses	**8.4**	**9.2**	**11.2**	**12.1**	**12.3**	**12.5**	**12.1**
CO_2	8.4	9.2	11.1	11.8	12.0	12.1	11.7
CH_4	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+
HFCs	+	+	0.1	0.2	0.3	0.3	0.4
Motorcycles	**1.8**	**1.8**	**1.9**	**1.7**	**1.9**	**2.1**	**2.2**
CO_2	1.7	1.8	1.8	1.6	1.9	2.1	2.1
CH_4	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+
Commercial Aircraft[a]	**136.8**	**143.1**	**170.9**	**162.8**	**138.5**	**139.5**	**123.4**
CO_2	135.4	141.6	169.2	161.2	137.1	138.1	122.2

CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	1.3	1.4	1.6	1.5	1.3	1.3	1.2
Other Aircraft[b]	**44.4**	**32.3**	**33.5**	**35.1**	**34.3**	**33.7**	**33.7**
CO_2	43.9	32.0	33.1	34.7	34.0	33.4	33.3
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Ships and Boats[c]	**45.1**	**58.6**	**61.3**	**45.2**	**48.4**	**55.2**	**38.7**
CO_2	44.5	57.7	60.2	44.5	47.7	54.4	38.1
CH_4	+	+	+	+	+	+	+
N_2O	0.6	0.8	0.9	0.6	0.7	0.8	0.5
HFCs	+	+	0.1	+	+	+	+
Rail	**38.9**	**43.6**	**48.0**	**52.9**	**55.1**	**54.3**	**50.6**
CO_2	38.5	42.7	45.5	50.3	52.3	51.5	47.8
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.3	0.3	0.3	0.4	0.4	0.4	0.4
HFCs	+	0.5	2.0	2.2	2.2	2.2	2.3
Other Emissions from Electricity Generation[d]	0.1	0.1	+	0.1	0.1	0.1	0.1
Pipelines[e]	**36.1**	**38.3**	**35.2**	**32.3**	**32.3**	**34.4**	**34.9**
CO_2	36.1	38.3	35.2	32.3	32.3	34.4	34.9
Lubricants	**11.8**	**11.3**	**12.1**	**10.2**	**9.9**	**10.2**	**9.5**
CO_2	11.8	11.3	12.1	10.2	9.9	10.2	9.5
Total Transportation	**1,548.2**	**1,698.3**	**1,935.8**	**2,020.9**	**1,997.5**	**2,008.6**	**1,890.8**
International Bunker Fuels[f]	*113.0*	*100.9*	*99.5*	*111.7*	*130.5*	*128.4*	*136.6*

Note: Totals may not sum due to independent rounding. Passenger cars and light-duty trucks include vehicles typically used for personal travel and less than 8500 lbs; medium- and heavy-duty trucks include vehicles larger than 8500 lbs. HFC emissions primarily reflect HFC-134a.

+ Does not exceed 0.05 Tg CO_2 Eq.

[a] Consists of emissions from jet fuel consumed by domestic operations of commercial aircraft (no bunkers).

[b] Consists of emissions from jet fuel and aviation gasoline consumption by general aviation and military aircraft.

[c] Fluctuations in emission estimates are associated with fluctuations in reported fuel consumption, and may reflect data collection problems.

[d] Other emissions from electricity generation are a result of waste incineration (as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants), electrical transmission and distribution, and a portion of limestone and dolomite use (from pollution control equipment installed in electricity generation plants).

[e] CO_2 estimates reflect natural gas used to power pipelines, but not electricity. While the operation of pipelines produces CH_4 and N_2O, these emissions are not directly attributed to pipelines in the US Inventory.

[f] Emissions from International Bunker Fuels include emissions from both civilian and military activities; these emissions are not included in the transportation totals.

Commercial

The commercial sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Energy-related emissions from the residential and commercial sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. Landfills and wastewater treatment are included in this sector, with landfill emissions decreasing since 1990, while wastewater treatment emissions have increased slightly.

Residential

The residential sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Emissions from the residential sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in

energy consumption caused by weather conditions, rather than prevailing economic conditions. In the long-term, this sector is also affected by population growth, regional migration trends, and changes in housing and building attributes (e.g., size and insulation).

Agriculture

The agricultural sector includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2008, enteric fermentation was the largest source of CH_4 emissions in the United States, and agricultural soil management was the largest source of N_2O emissions in the United States. This sector also includes small amounts of CO_2 emissions from fossil fuel combustion by motorized farm equipment like tractors.

Electricity Generation

The process of generating electricity, for consumption in the above sectors, is the single largest source of greenhouse gas emissions in the United States, representing 34 percent of total U.S. emissions. Electricity generation also accounted for the largest share of CO_2 emissions from fossil fuel combustion, approximately 42 percent in 2008. Electricity was consumed primarily in the residential, commercial, and industrial end-use sectors for lighting, heating, electric motors, appliances, electronics, and air conditioning.

[BEGIN BOX]

Box 2-1: Methodology for Aggregating Emissions by Economic Sector

In presenting the Economic Sectors in the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks, the Inventory expands upon the standard IPCC sectors common for UNFCCC reporting. Discussing greenhouse gas emissions relevant to U.S.-specific sectors improves communication of the report's findings.

In the Electricity Generation economic sector, CO_2 emissions from the combustion of fossil fuels included in the EIA electric utility fuel consuming sector are apportioned to this economic sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA electric utility sector. Additional sources include CO_2, CH_4, and N_2O from waste incineration, as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants. The Electricity Generation economic sector also includes SF_6 from Electrical Transmission and Distribution, and a portion of CO_2 from Limestone and Dolomite Use (from pollution control equipment installed in electricity generation plants).

In the Transportation economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA transportation fuel consuming sector are apportioned to this economic sector (additional analyses and refinement of the EIA data is further explained in the Energy chapter of this report). Additional emissions are apportioned from the CH_4 and N_2O from Mobile Combustion, based on the EIA transportation sector. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with emissions from transportation refrigeration/air-conditioning systems to this economic sector. Finally, CO_2 emissions from Non-Energy Uses of Fossil Fuels identified as lubricants for transportation vehicles are included in the Transportation economic sector.

For the Industry economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA industrial fuel consuming sector, minus the agricultural use of fuel explained below, are apportioned to this economic sector. Stationary and mobile combustion emissions of CH_4 and N_2O are also based on the EIA industrial sector, minus emissions apportioned to the Agriculture economic sector described below. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with most emissions falling within the Industry economic sector (minus emissions from the other economic sectors). Additionally, all process-related emissions from sources with methods considered within the IPCC Industrial Process guidance have been apportioned to this economic sector. This includes the process-related emissions (i.e., emissions from the actual process to make the material, not from fuels to power the plant) from such activities as cement production, iron and steel production and metallurgical coke production, and Ammonia Production.

Additionally, fugitive emissions from energy production sources, such as Natural Gas Systems, Coal Mining, and Petroleum Systems are included in the Industry economic sector. A portion of CO_2 from Limestone and Dolomite Use (from pollution control equipment installed in large industrial facilities) are also included in the Industry economic sector. Finally, all remaining CO_2 emissions from Non-Energy Uses of Fossil Fuels are assumed to be industrial in nature (besides the lubricants for transportation vehicles specified above), and are attributed to the Industry economic sector.

As agriculture equipment is included in EIA's industrial fuel consuming sector surveys, additional data is used to extract the fuel used by agricultural equipment, to allow for accurate reporting in the Agriculture economic sector from all sources of emissions, such as motorized farming equipment. Energy consumption estimates are obtained from Department of Agriculture survey data, in combination with separate EIA fuel sales reports. This supplementary data is used to apportion CO_2 emissions from fossil fuel combustion, and CH_4 and N_2O emissions from stationary and mobile combustion (all data is removed from the Industrial economic sector, to avoid double-counting). The other emission sources included in this economic sector are intuitive for the agriculture sectors, such as N_2O emissions from Agricultural Soils, CH_4 from Enteric Fermentation (i.e., exhalation from the digestive tracts of domesticated animals), CH_4 and N_2O from Manure Management, CH_4 from Rice Cultivation, CO_2 emissions from liming of agricultural soils and urea application, and CH_4 and N_2O from Forest Fires. N_2O emissions from the application of fertilizers to tree plantations (termed "forest land" by the IPCC) are also included in the Agriculture economic sector.

The Residential economic sector includes the CO_2 emissions from the combustion of fossil fuels reported for the EIA residential sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA residential fuel consuming sector. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with emissions from residential air-conditioning systems to this economic sector. N_2O emissions from the application of fertilizers to developed land (termed "settlements" by the IPCC) are also included in the Residential economic sector.

The Commercial economic sector includes the CO_2 emissions from the combustion of fossil fuels reported in the EIA commercial fuel consuming sector data. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA commercial sector. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with emissions from commercial refrigeration/air-conditioning systems to this economic sector. Public works sources including direct CH_4 from Landfills and CH_4 and N_2O from Wastewater Treatment and Composting are included in this economic sector.

[END BOX]

[BEGIN BOX]

Box 2-2: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and non-utilities combined—was the largest source of U.S. greenhouse gas emissions in 2008; (4) emissions per unit of total gross domestic product as a measure of national economic activity; or (5) emissions per capita.

Table 2-16 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.7 percent since 1990. This rate is slightly slower than that for total energy consumption and growth in national population since 1990 and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions are growing at a rate similar to that of fossil fuel consumption since 1990 (see Table 2-16).

Table 2-16: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990	1995	2000	2005	2006	2007	2008	Growth Rate[a]
GDP[b]	100	113	140	157	162	165	166	2.9%
Electricity Consumption[c]	100	112	127	134	135	138	136	1.8%
Fossil Fuel Consumption[c]	100	107	117	119	117	119	115	0.8%
Energy Consumption[c]	100	107	116	119	118	120	118	0.9%
Population[d]	100	107	113	118	119	120	121	1.1%
Greenhouse Gas Emissions[e]	100	106	115	116	115	117	114	0.7%

[a] Average annual growth rate
[b] Gross Domestic Product in chained 2000 dollars (BEA 2009)
[c] Energy-content-weighted values (EIA 2008)
[d] U.S. Census Bureau (2008)
[e] GWP-weighted values

Figure 2-14: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product
Source: BEA (2008), U.S. Census Bureau (2008), and emission estimates in this report.

[END BOX]

2.3. Indirect Greenhouse Gas Emissions (CO, NO_x, NMVOCs, and SO_2)

The reporting requirements of the UNFCCC[44] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases. Carbon monoxide is produced when carbon-containing fuels are combusted incompletely. Nitrogen oxides (i.e., NO and NO_2) are created by lightning, fires, fossil fuel combustion, and in the stratosphere from N_2O. Non-CH_4 volatile organic compounds—which include hundreds of organic compounds that participate in atmospheric chemical reactions (i.e., propane, butane, xylene, toluene, ethane, and many others)—are emitted primarily from transportation, industrial processes, and non-industrial consumption of organic solvents. In the United States, SO_2 is primarily emitted from coal combustion for electric power generation and the metals industry. Sulfur-containing compounds emitted into the atmosphere tend to exert a negative radiative forcing (i.e., cooling) and therefore are discussed separately.

One important indirect climate change effect of NMVOCs and NO_x is their role as precursors for tropospheric ozone formation. They can also alter the atmospheric lifetimes of other greenhouse gases. Another example of indirect greenhouse gas formation into greenhouse gases is CO's interaction with the hydroxyl radical—the major atmospheric sink for CH_4 emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy CH_4.

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2009),[45] which are regulated under the Clean Air Act. Table 2-17 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Table 2-17: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

[44] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

[45] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2009).

Gas/Activity	1990	1995	2000	2005	2006	2007	2008
NO_x	**21,728**	**21,227**	**19,145**	**15,933**	**15,071**	**14,410**	**13,578**
Mobile Fossil Fuel Combustion	10,862	10,536	10,199	9,012	8,488	7,965	7,441
Stationary Fossil Fuel Combustion	10,023	9,862	8,053	5,858	5,545	5,432	5,148
Industrial Processes	591	607	626	569	553	537	520
Oil and Gas Activities	139	100	111	321	319	318	318
Incineration of Waste	82	88	114	129	121	114	106
Agricultural Burning	30	30	37	40	40	38	40
Solvent Use	1	3	3	3	4	4	4
Waste	0	1	2	2	2	2	2
CO	**130,536**	**109,114**	**92,872**	**71,555**	**67,909**	**64,348**	**60,739**
Mobile Fossil Fuel Combustion	119,360	97,630	83,559	62,692	58,972	55,253	51,533
Stationary Fossil Fuel Combustion	5,000	5,383	4,340	4,649	4,695	4,744	4,792
Industrial Processes	4,125	3,959	2,216	1,555	1,597	1,640	1,682
Incineration of Waste	978	1,073	1,670	1,403	1,412	1,421	1,430
Agricultural Burning	766	745	888	930	905	960	970
Oil and Gas Activities	302	316	146	318	319	320	322
Waste	1	2	8	7	7	7	7
Solvent Use	5	5	45	2	2	2	2
NMVOCs	**20,930**	**19,520**	**15,227**	**13,761**	**13,594**	**13,423**	**13,254**
Mobile Fossil Fuel Combustion	10,932	8,745	7,229	6,330	6,037	5,742	5,447
Solvent Use	5,216	5,609	4,384	3,851	3,846	3,839	3,834
Industrial Processes	2,422	2,642	1,773	1,997	1,933	1,869	1,804
Stationary Fossil Fuel Combustion	912	973	1,077	716	918	1,120	1,321
Oil and Gas Activities	554	582	388	510	510	509	509
Incineration of Waste	222	237	257	241	238	234	230
Waste	673	731	119	114	113	111	109
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**16,891**	**14,830**	**13,466**	**12,388**	**11,799**	**10,368**
Stationary Fossil Fuel Combustion	18,407	14,724	12,849	11,541	10,612	10,172	8,891
Industrial Processes	1,307	1,117	1,031	831	818	807	795
Mobile Fossil Fuel Combustion	793	672	632	889	750	611	472
Oil and Gas Activities	390	335	287	181	182	184	187
Incineration of Waste	38	42	29	24	24	24	23
Waste	0	1	1	1	1	1	1
Solvent Use	0	1	1	0	0	0	0
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

Source: (EPA 2009) except for estimates from field burning of agricultural residues.
NA (Not Available)
Note: Totals may not sum due to independent rounding.

[BEGIN BOX]

Box 2-3: Sources and Effects of Sulfur Dioxide

Sulfur dioxide (SO_2) emitted into the atmosphere through natural and anthropogenic processes affects the earth's radiative budget through its photochemical transformation into sulfate aerosols that can (1) scatter radiation from the sun back to space, thereby reducing the radiation reaching the earth's surface; (2) affect cloud formation; and (3) affect atmospheric chemical composition (e.g., by providing surfaces for heterogeneous chemical reactions). The

indirect effect of sulfur-derived aerosols on radiative forcing can be considered in two parts. The first indirect effect is the aerosols' tendency to decrease water droplet size and increase water droplet concentration in the atmosphere. The second indirect effect is the tendency of the reduction in cloud droplet size to affect precipitation by increasing cloud lifetime and thickness. Although still highly uncertain, the radiative forcing estimates from both the first and the second indirect effect are believed to be negative, as is the combined radiative forcing of the two (IPCC 2001). However, because SO_2 is short-lived and unevenly distributed in the atmosphere, its radiative forcing impacts are highly uncertain.

Sulfur dioxide is also a major contributor to the formation of regional haze, which can cause significant increases in acute and chronic respiratory diseases. Once SO_2 is emitted, it is chemically transformed in the atmosphere and returns to the earth as the primary source of acid rain. Because of these harmful effects, the United States has regulated SO_2 emissions in the Clean Air Act.

Electricity generation is the largest anthropogenic source of SO_2 emissions in the United States, accounting for 86 percent in 2008. Coal combustion contributes nearly all of those emissions (approximately 92 percent). Sulfur dioxide emissions have decreased in recent years, primarily as a result of electric power generators switching from high-sulfur to low-sulfur coal and installing flue gas desulfurization equipment.

[END BOX]

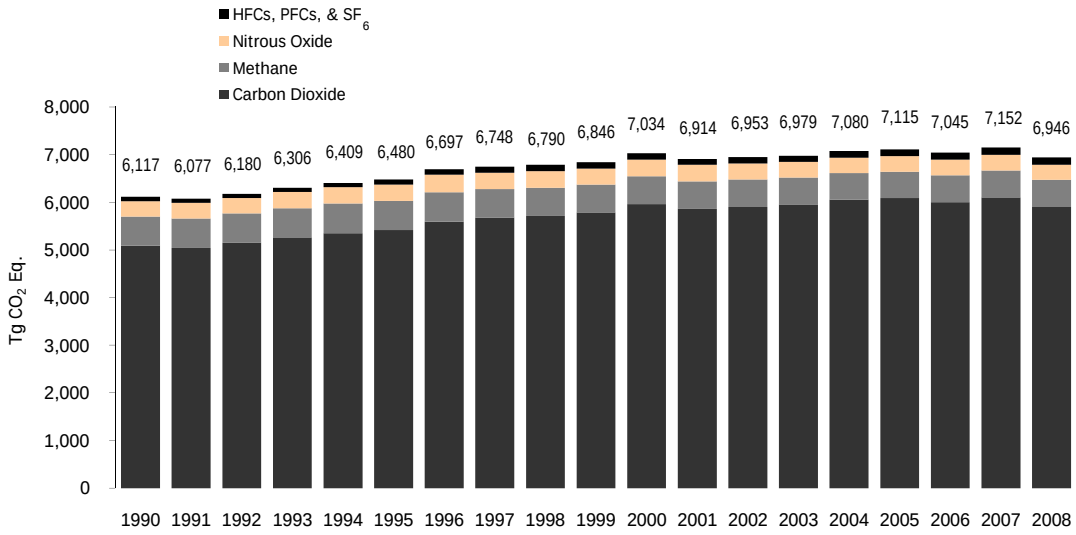


Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

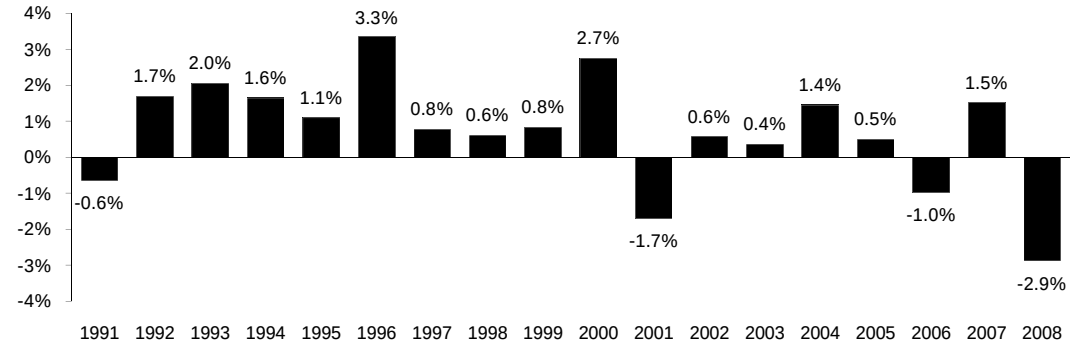


Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

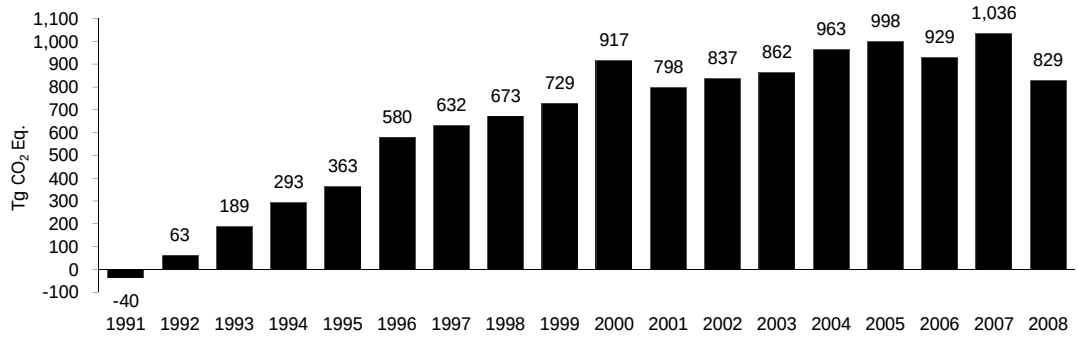
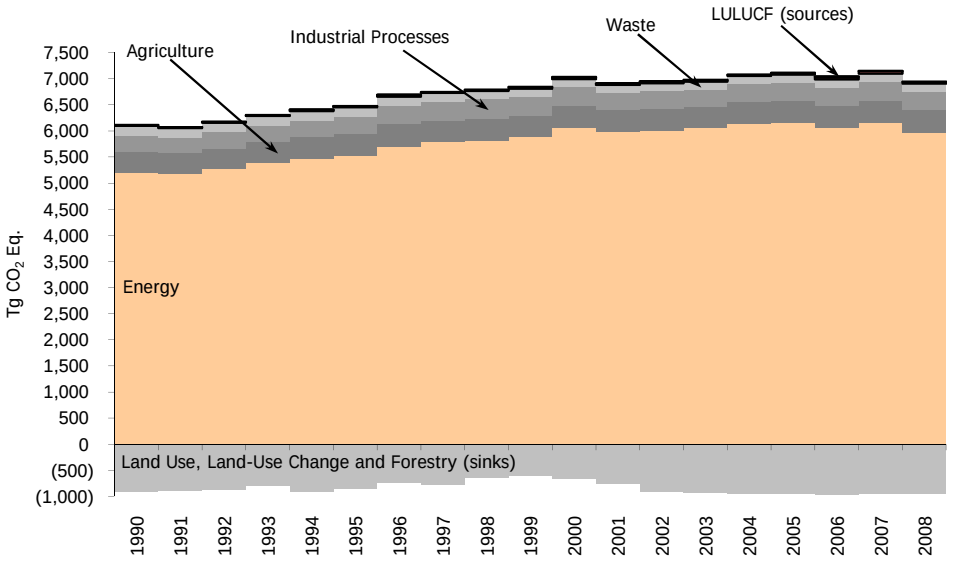


Figure 2-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990



Note: Relatively smaller amounts of GWP-weighted emissions are also emitted from the Solvent and Other Product Use sector

Figure 2-4: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

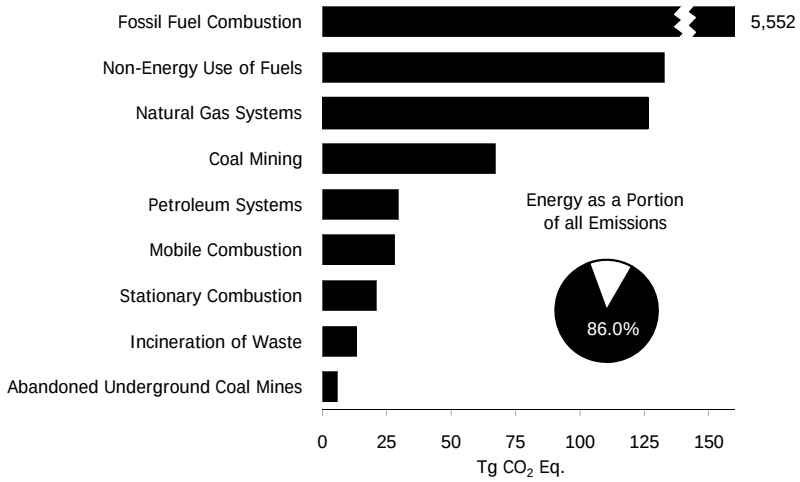


Figure 2-5: 2008 Energy Sector Greenhouse Gas Sources

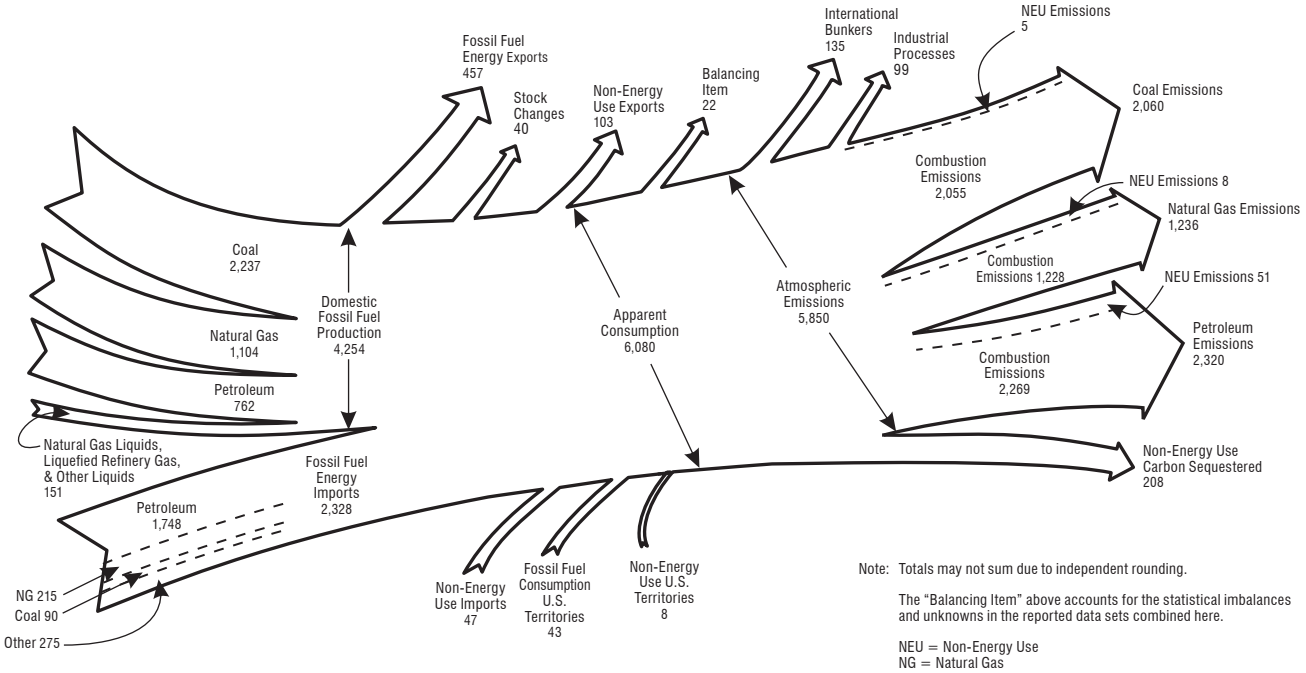


Figure 2-6 2008 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)

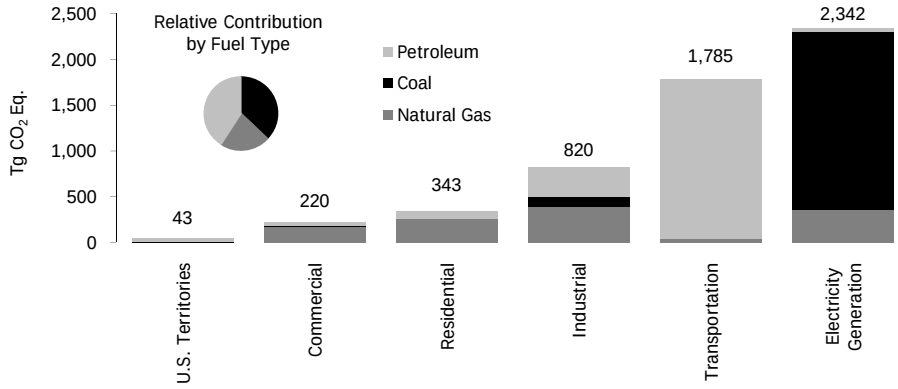


Figure 2-7: 2008 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Note: Electricity generation also includes emissions of less than 0.5 Tg CO_2 Eq. from geothermal-based electricity generation.

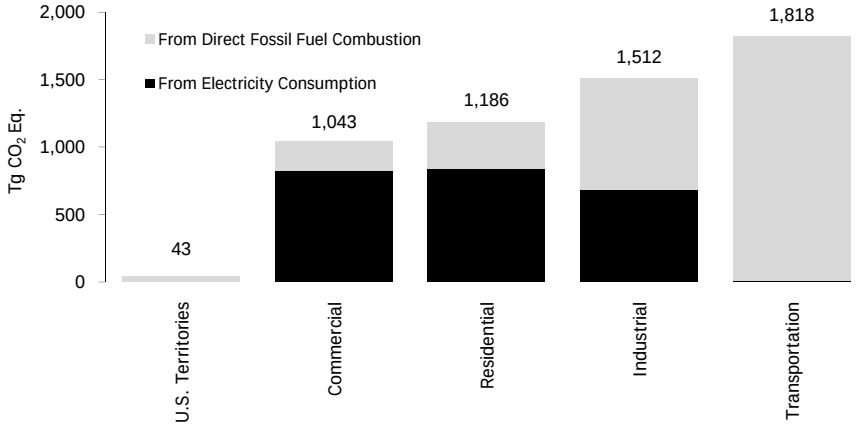


Figure 2-8: 2008 End-Use Sector Emissions of CO_2, CH_4, and N_2O from Fossil Fuel Combustion

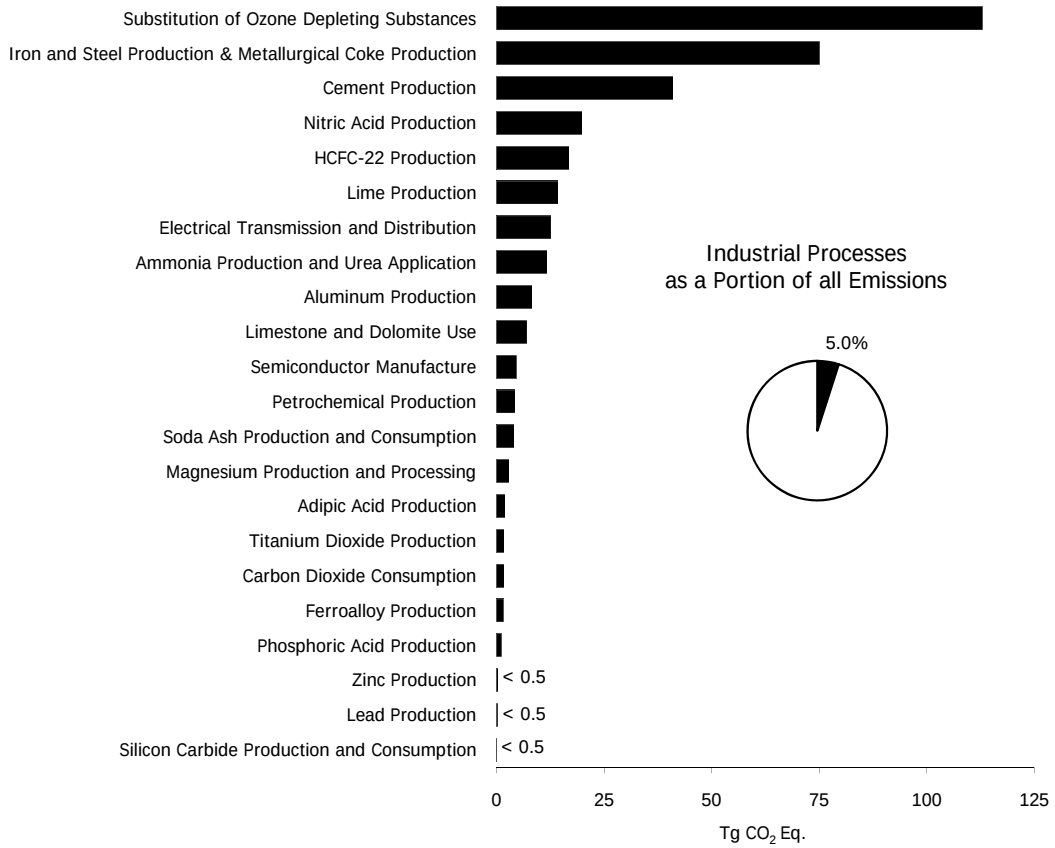


Figure 2-9: 2008 Industrial Processes Chapter Greenhouse Gas Sources

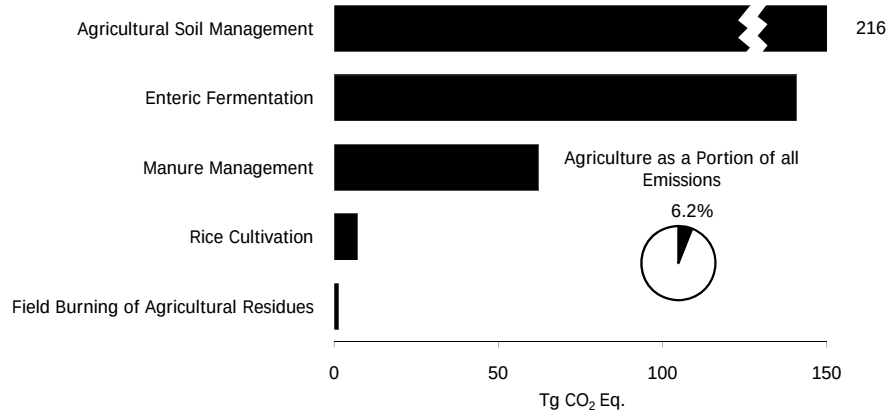


Figure 2-10: 2008 Agriculture Chapter Greenhouse Gas Sources

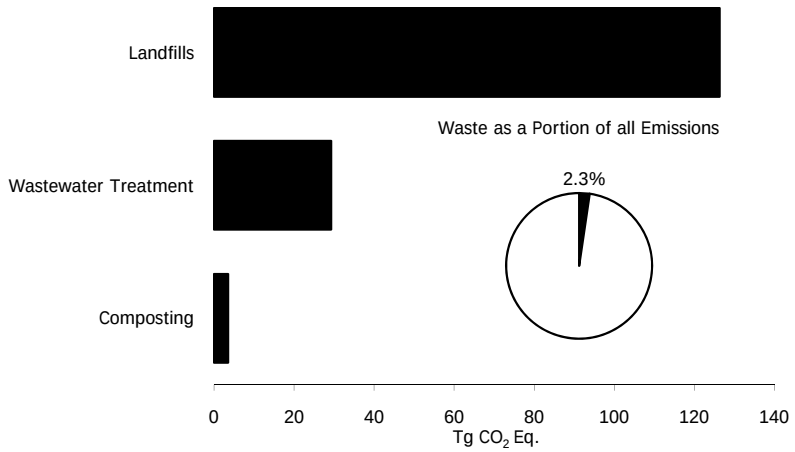


Figure 2-11: 2008 Waste Chapter Greenhouse Gas Sources

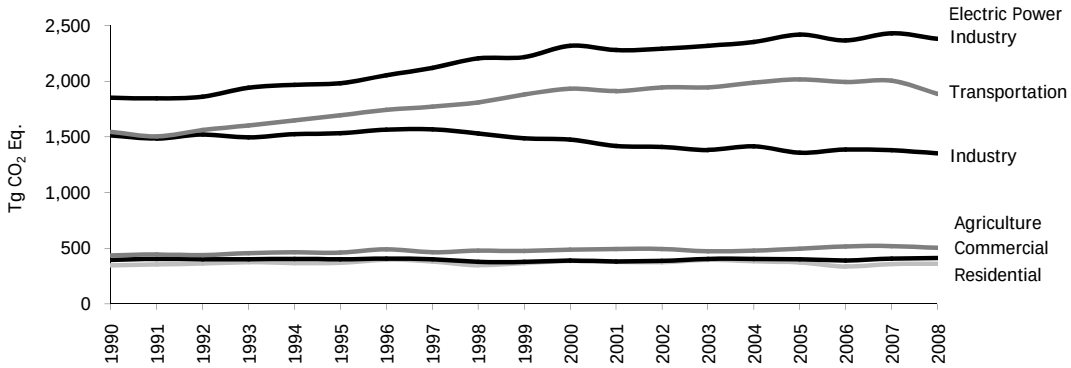


Figure 2-12: Emissions Allocated to Economic Sectors

Note: Does not include U.S. Territories.

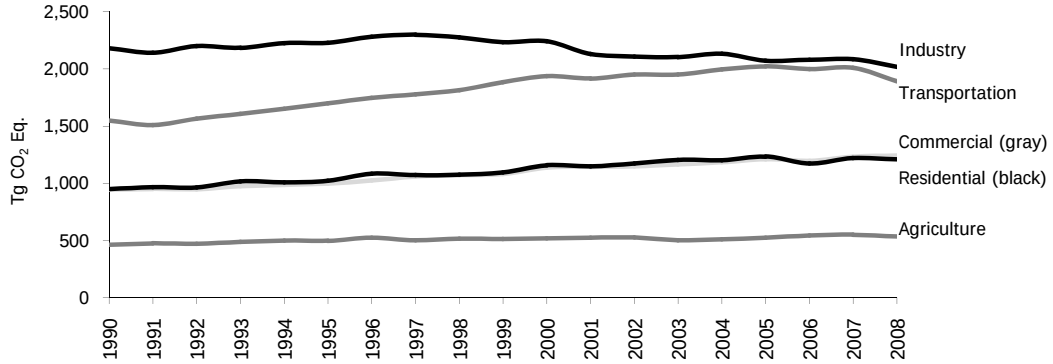


Figure 2-13: Emissions with Electricity Distributed to Economic Sectors

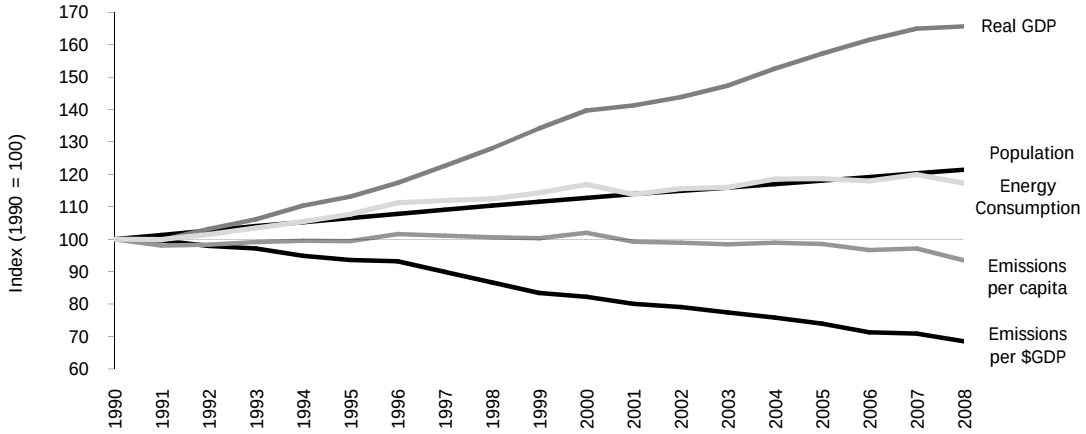


Figure 2-14: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product